HM Revenue & Customs

Knowledge, Analysis, and Intelligence (KAI)

Estimation of price elasticities of demand for alcohol in the United Kingdom

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December 2014

HMRC Working Paper 16

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Abstract

Price elasticities of demand for alcohol products are used by HMRC to quantify changes in alcohol consumption in response to changes in price of alcohol. They are one of the key inputs to HMRC's estimates of the tax revenue impacts of changes in UK alcohol duty rates. This paper estimates own- and cross-price elasticities in both the on- and the off-trade for all five major categories of alcohol: beer, wine, cider, spirits and 'ready-to-drink' products. We use data from the Living Costs and Food Survey from 2007 to 2012 and estimate a Heckman correction model in order to distinguish between zero observations caused by price and non-price reasons.

All the own-price elasticity estimates are negative and highly significant, while a number of cross-price elasticity estimates are also significant. Spirits in the on-trade and beer and cider in the off-trade are found to be the most price elastic types of alcohol, while 'ready-to-drinks' in the on-trade and wine in both the on- and off-trade are found to be the least price responsive types of alcohol. The results are found to be stable across a number of specifications, and represent an improvement in terms of accuracy of the inputs used in HMRC's costings model, making use of more recent data and an updated methodology.

JEL codes: C34, D12

Keywords: Sample selection, elasticity of demand, alcohol

Acknowledgements and disclaimer

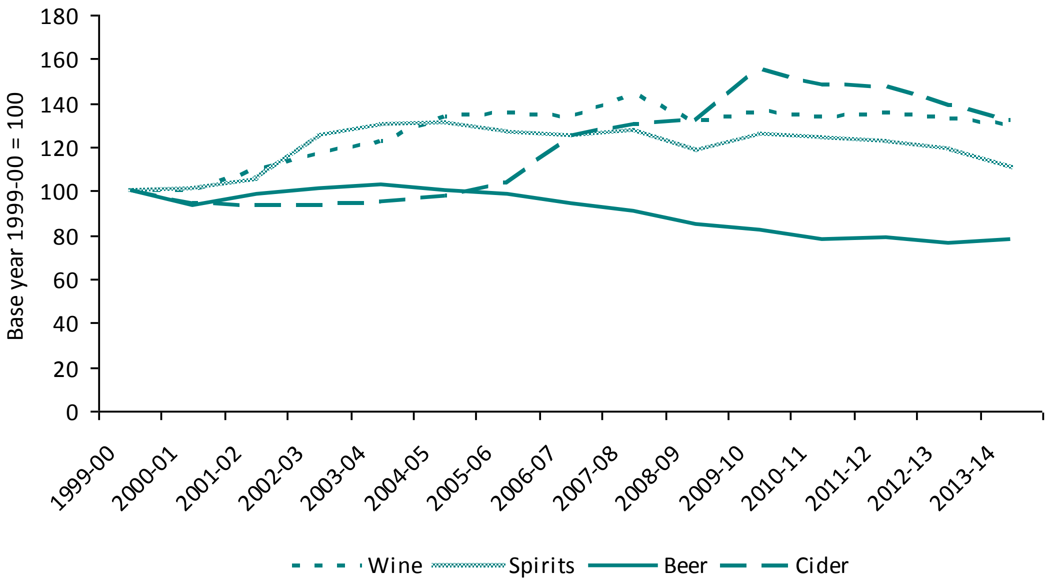
The work presented in this paper would not have been possible without the input from colleagues both in and outside HMRC. I am particularly grateful to Juliet Clarke, Antony Long and Nick Catton in HMRC and to Peter Urwin and Augusto Cerqua at the University of Westminster for their valuable contributions that have improved this study a great deal. Any remaining errors are my own responsibility.

1. Background

HM Government collected £10.5 billion in alcohol duties in 2013-14, around 2 per cent of all tax revenue collected by HM Revenue and Customs (HMRC). Most of the revenue came from wine (£3.7 billion), beer (£3.3 billion) and spirits (£3.1 billion), with cider making a small contribution to receipts (£0.3 billion). Alcohol duty's contribution to HMRC receipts has remained around 2 per cent since the creation of the department in 2005 from the merger of Inland Revenue and HM Customs and Excise.

There has been a significant change in the alcohol market, as well as in terms of the contribution of each type of alcohol to HMRC receipts. Graph 1A shows the trends in clearances of each product since 1999-00. Clearances refer to all alcohol that has been released for consumption in the UK after duty has been paid to HMRC. Since 1999-00, clearances of wine and cider have increased considerably. Clearances of spirits are slightly above 1999-00 levels, while beer clearances have been on a long-term downward trend.

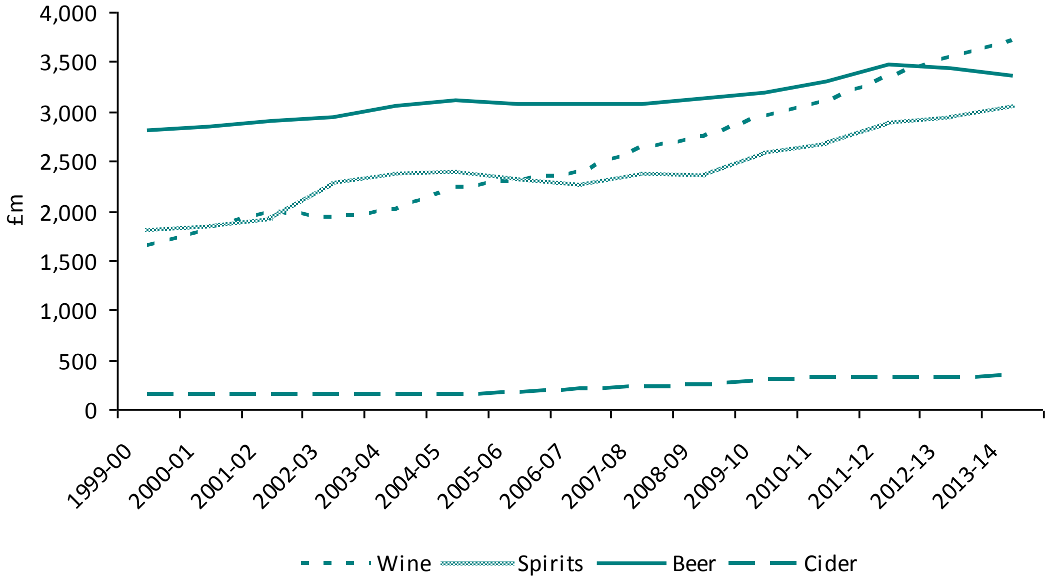
Graph 1A: Indexed alcohol clearances (base year 1999-00)



Graph 1B shows the contribution of each type of alcohol to HMRC's receipts since 1999-00. Beer has historically been the largest source of alcohol revenues for HMRC; however, in line with the trend in Graph 1A, wine receipts have been increasing over time, surpassing beer as the largest contributor to receipts in 2012-13. Spirits receipts have also been increasing steadily over time, and are forecast by the Office for Budget Responsibility[1] to top beer duty receipts before the end of its forecast period in 2019-20. Cider receipts have more than doubled since 1999-00, but remain a small portion of alcohol receipts overall.

[1] The Office for Budget Responsibility's forecasts for alcohol receipts are available in their December 2014 Economic and Fiscal Outlook at http://budgetresponsibility.org.uk/economic-fiscal-outlook-december-2014.

Graph 1B: Tax receipts by type of alcohol (1999-00 to 2013-14)



The alcohol market can be divided into the on- and the off-trade. On-trade refers to alcohol sold to be consumed on the premises (pubs, bars, restaurants), and off-trade refers to alcohol sold to be consumed off the premises (shops). Duty does not depend on whether alcohol is sold in the on- or the off-trade, but we expect different behavioural responses to price changes depending on the location of purchase. Consumption decisions in the on-trade also depend on differentiating factors relating to the establishment where alcohol is being consumed, which are less important in the off-trade. Therefore, as in previous HMRC studies, we estimate separate elasticities for the on- and the off-trade for each type of drink.

The objective of this study is to estimate own- and cross-price elasticities of demand for the main categories of alcoholic products in the United Kingdom: beer, wine, spirits, cider and 'ready-to-drink' products (RTDs)[2]. HMRC's alcohol policy costings model is used to estimate the effect of changes in alcohol duty rates on revenues to the Exchequer. The model makes use of a number of inputs, including forecasts of alcohol receipts, duty rates, prices and other macroeconomic variables. In addition, the model makes use of price elasticities of demand in order to estimate behavioural responses to changes in alcohol duty rates.

The new elasticities presented in this working paper are estimated using more recent data and an updated methodology compared to those previously published by HMRC. Having undertaken robust quality assurance processes, we are confident that they more accurately reflect the behavioural responses of consumers to prices in the current market.

The structure of this paper is as follows: section 2 updates the literature review published in the previous HMRC study of alcohol consumption (Collis et al, 2010); section 3 describes the dataset used for the estimation process; section 4 explains the methodology used, in particular the Heckman correction model and the variables selected; section 5 presents the results of our estimation procedure; section 6 explores robustness checks and alternative specifications; section 7 shows the impact of the new elasticities on policy costings; and section 8 summarises the main findings from the paper.

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[2] RTDs are alcoholic drinks to be consumed with a mixer and sold in pre-packaged form (for example, pre-mixed gin and tonic).

2. Literature review

2.1. Demand for alcohol

Demand for alcohol is affected by a variety of factors other than price such as income, licensing restrictions, social and legal factors, among others. With respect to price, the existing literature clearly suggests that the demand curve for alcoholic beverages, both individually and as a whole, slopes downward and that demand for alcohol is relatively inelastic, with -0.5 being reported by international meta-studies such as Gallet (2007) and Wagenaar et al (2009).

Most studies of price elasticities of demand for alcohol have historically focused on own-price elasticity estimates for the three main types of alcoholic drinks – beer, wine and spirits – without distinction between the on- and the off-trade. However, studies that have allowed for different consumption responses in the on- and off-trade – Huang (2003), Collis et al (2010), Meng et al (2014) at the University of Sheffield – have found them to be quite distinct for most alcohols types.

Cross-sectional surveys have historically been a common source of data for the purpose of estimating alcohol demand elasticities. As mentioned in Collis et al (2010), there are well-known problems with self-reporting of alcohol consumption in survey data – Midanik (1982) suggests that only around half of all consumption might be captured, and this is corroborated by Meng et al (2014), who find that their data covers from 55% to 66% of consumption in the years from 2001 to 2009. In addition to this, there is likely to be bias in the sampling of the survey; this is particularly relevant if the individuals omitted from surveys were also significant consumers of alcohol. If not controlled for, this could lead to significant bias, which reinforces the importance of controlling for sample selection.

2.2. Historical estimates

Tables 2A and 2B summarise historical estimates[3] of UK price elasticities for beer, wine and spirits and the range of estimates from UK alcohol studies, respectively.

Table 2A: Historical estimated UK price elasticities for beer, wine and spirits

Author	Time Period	Beer	Wine	Spirits
Stone (1945)	1920-1938	-0.73	---	-0.72
Prest (1949)	1870-1938	-0.66	---	-0.57
Stone (1951)	1920-1948	-0.69	-1.17	-0.57
HM Treasury (1980)	1980	-0.20	-1.10	-1.60
Walsh (1982)	1955-1975	-0.13	-0.28	-0.47
Duffy (1983)	1963-1978	---	-1.00	-0.77
McGuinness (1983)	1956-1979	-0.30	-0.17	-0.38
Clements and Selvanathan (1987)	1955-1975	-0.19	-0.23	-0.24
Duffy (1987)	1963-1983	-0.29	-0.77	-0.51
Godfrey (1988)	1956-1980	---	-0.67	-0.72
Godfrey (1988)	1956-1980	---	-0.95	-1.49
Selvanathan (1988)	1955-1985	-0.13	-0.37	-0.32
Wong (1988)	1920-1938	-0.25	-0.99	-0.51
Crooks (1989)	1970-1988	-1.05	-2.42	-0.91

[3] Tables 2A and 2B are updated versions of tables present originally in Collis et al (2010).

Author	Time Period	Beer	Wine	Spirits
Jones (1989)	1964-1983	-0.40	-0.94	-0.79
Jones (1989)	1964-1983	-0.27	-0.77	-0.95
Selvanathan (1989)	1955-1975	-0.25	-0.22	-0.20
Baker and McKay (1990)	1970-1986	-0.88	-1.37	-0.94
Baker et al (1990)	1970-1986	-0.99	-0.92	-1.12
Cuthbertson and Ormerod (1991)	1965-1989	-0.30	-0.49	-0.30
Duffy (1991)	1963-1983	-0.09	-0.75	-0.86
Selvanathan (1991)	1955-1985	-0.13	-0.40	-0.31
Crawford and Tanner (1995)	1974-1994	-0.67	-1.40	-1.20
Blake and Nied (1997)	1952-1992	-0.95	-1.32	-0.93
Clements et al (1997)	1955-1985	-0.44	-0.57	-0.72
Salisu and Balasubramanyam (1997)	1963-1993	-0.10	-1.16	-0.66
Chambers (1999)	1963-1998	-0.60	-1.20	-0.40
Crawford et al (1999)	1978-1996	-0.75	-1.70	-0.86
Duffy (2002)	1963-1999	-0.39	-0.14	-0.67
Moosa and Baxter (2002)	1964-1995	-3.20	-2.30	---
Duffy (2003)	1963-1996	-0.41	-0.79	-1.36
Huang (2003)	1970-2002	-0.48*	---	-1.31
		-1.03**	---	---
Selvanathan and Selvanathan (2005)	1955-2002	-0.27	-0.35	-0.56
Collis et al (2010)	2001-2006	-0.77*	-0.46*	-1.16*
		-1.11**	-0.54**	-0.90**
Meng et al (2014)	2001-2009	-0.79*	-0.87*	-0.89*
		-0.98**	-0.38**	-0.08**

* denotes an on-trade elasticity only; ** denotes an off-trade elasticity only.

Table 2B: Range of estimates from UK alcohol studies

Alcohol type	Literature median	Literature mean	Literature range
Beer	-0.44	-0.60	-0.09 to -3.20
Wine	-0.78	-0.86	-0.14 to -2.42
Spirits	-0.72	-0.75	-0.08 to -1.60

Gallet (2007), a meta-study looking at estimates across several countries, finds wine and spirits were consistently more elastic than beer, though a number of recent UK studies have found the wine elasticity to be below both the mean and median found in the literature. Other findings of interest include double-log functional forms not being found to produce significantly different results to linear OLS regressions; and maximum likelihood estimators producing less elastic estimates than least squares.

3. Dataset

3.1. The Living Costs and Food Survey (LCF)

Our dataset was generated from the Living Costs and Food (LCF) survey, a household-level survey which is run together by the Office for National Statistics (ONS) and the Department for the Environment, Food and Rural Affairs (Defra). We have used data in calendar years from 2007 to 2012, the six most recent years of data available at UK Data Archive[4]. The LCF contains both household-level information (around expenditure) and personal questions (around attitudes).

The LCF[5] is the largest cross-sectional survey run in the UK, with approximately 12,000 different households surveyed every year and a response rate of around 50%. Two modules were used to create this dataset: the main LCF survey and Defra's Family Food Module, which contains both expenditure by item and quantities purchased. Annex 1 contains detailed information about the fields used to create the variables used in the analysis.

3.2. Missing prices

The prices we use in the dataset are derived from the LCF dataset, and we obtain them by dividing expenditure by quantities purchased at household level. Because of the way prices are derived, they will be missing for all households which do not purchase a particular type of alcohol. Because we want to include these zero consumption observations in the dataset for the final estimation, we need to impose prices on these observations.

We do this by calculating average prices for different subsets of the dataset. We first calculate average prices by region, year and household size (e.g. average prices for a household of four people in the North East in 2011), as these factors may affect average price; for example, larger households may face different prices by buying in larger quantities. We then substitute the missing prices with these average prices. If it is not possible to calculate average price using household size due to small sample sizes, we calculate prices by region and year, and then substitute the missing prices with these average prices.

While this approach has limitations – particularly the fact that we cannot observe the actual prices faced by households, which might be different from the average of the subset in which they fit – we believe that this is a reasonable adjustment, as it takes into account changes in prices over time as well as price differences across regions in the UK.

3.3. Conversion to real prices

To estimate consistent elasticities and to ensure identification of actual demand responses, we need to adjust prices for inflation. We have used the quarterly Consumer Price Index (CPI) series, published by the ONS on a monthly basis. Although the base period makes no difference for the purpose of the calculations, we have for reference used Quarter 3 of 2009 as the base period.

3.4. Descriptive statistics of the dataset

The dataset is balanced and generally reflects the UK population in a number of dimensions – geographical spread, ethnicity and socio-economic classification (of the reference person of the household for the latter two) – as shown in the graphs below. The main issue with the

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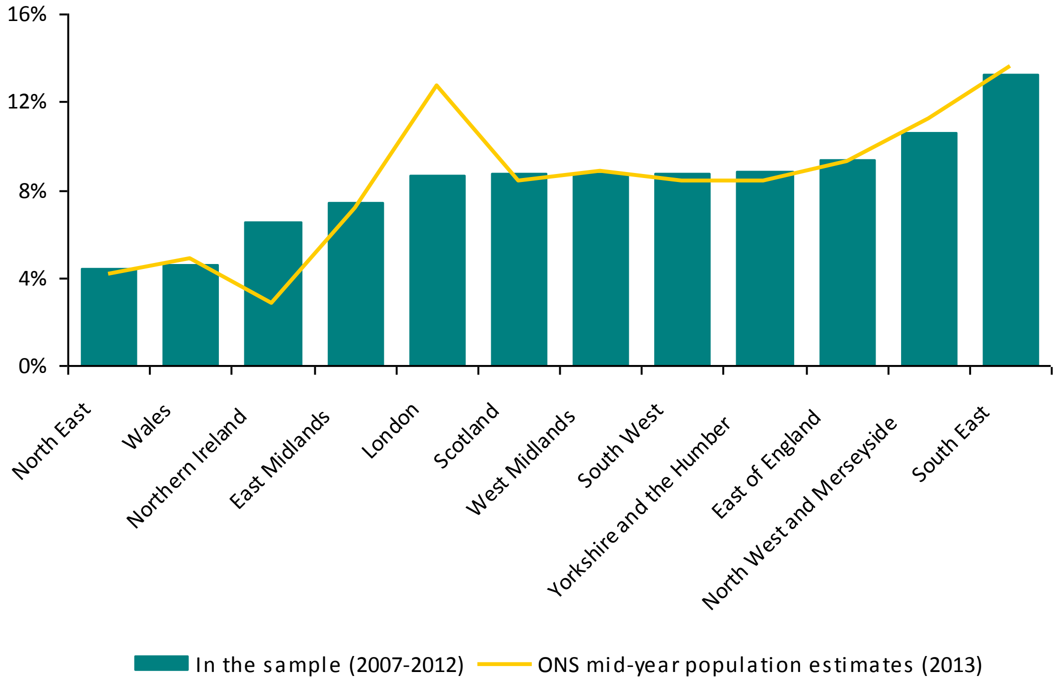
[4] The data from the LCF is available at http://discover.ukdataservice.ac.uk/series/?sn=2000028.

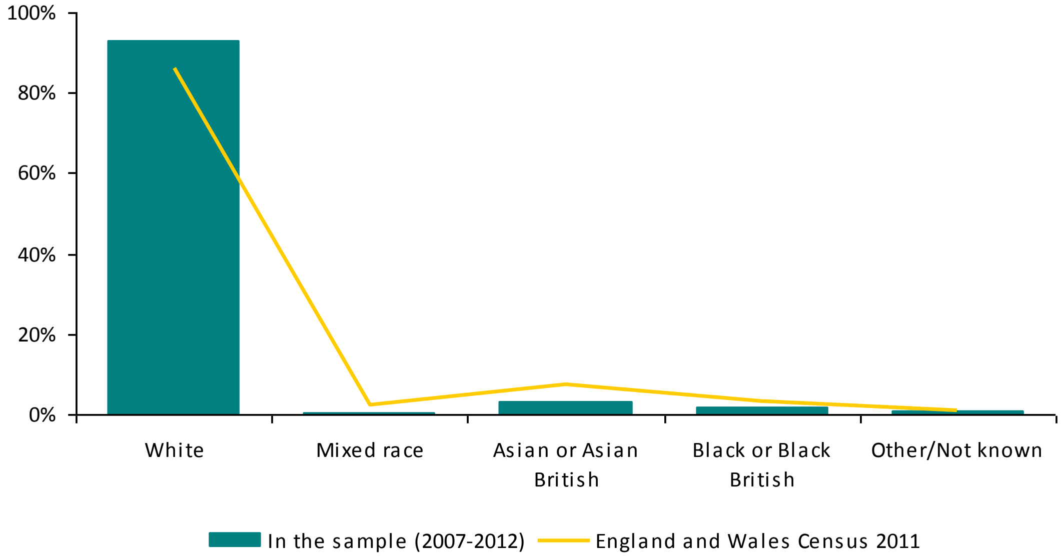
[5] The LCF was known as the Expenditure and Food Survey, or EFS, prior to 2008, and the Family Expenditure Survey and the National Food Survey prior to 2000-01. It was run in financial years from 2000-01 to 2005-06 and in calendar years from then on, making 2007 the first full calendar year for which it is available.

sample is the under-representation of London and the over-representation of Northern Ireland; however, sensitivity analysis has shown that the results are not significantly changed by excluding Northern Ireland or by estimating separate regressions for London.

Graph 3A: Distribution of observations in the dataset across regions (2007-2012)



Graph 3B: Distribution of observations in the dataset across ethnic background (2007-2012)



Graph 3C: Distribution[6] of observations in the dataset across socio-economic group (2007-2012)

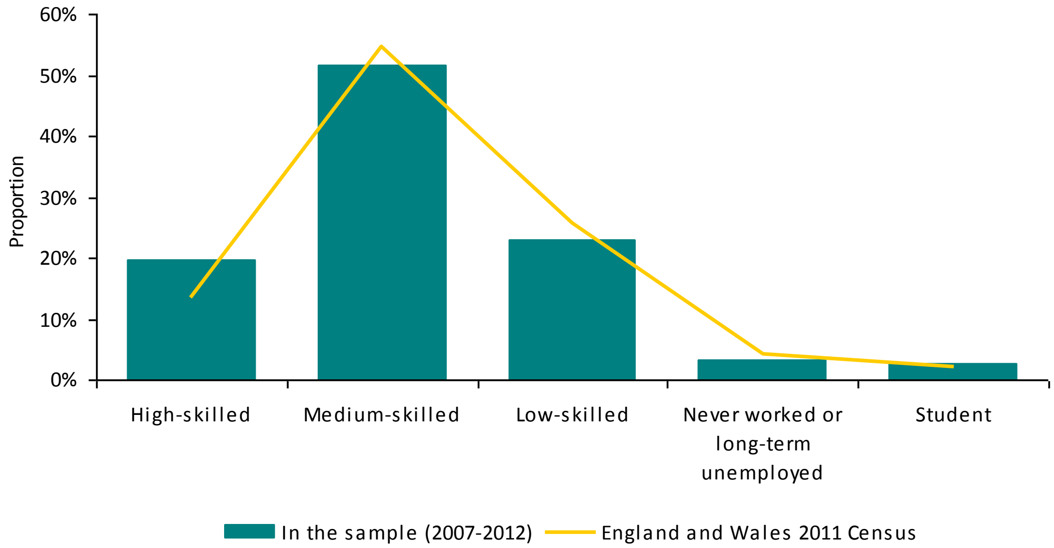


Table 3A shows the proportion of the sample that consumes each type of drink, as well as the proportion of drinking and non-drinking households. The proportion of non-drinking households is similar to that in the years used in the 2010 HMRC study. The main difference is in the proportion of beer-drinking households in the on-trade, which has decreased from 41% to 33%. We also observe an increase in the proportion of cider-drinking households and a fall in the proportion of spirits- and RTDs-drinking households relative to the 2010 study.

Table 3A: Drinking statistics from the dataset

	This paper		2010 study
	Frequency	Proportion of sample	Proportion of sample
Drinking households	22,713	66%	69%
Non-drinking households	11,613	34%	31%
Households consuming alcohol in the on-trade	14,410	42%	49%
Households consuming alcohol in the off-trade	18,033	53%	53%
Households consuming beer	15,292	45%	51%
Households consuming beer in the on-trade	11,305	33%	41%
Households consuming beer in the off-trade	8,051	23%	25%
Households consuming wine	14,766	43%	43%
Households consuming wine in the on-trade	6,517	19%	20%
Households consuming wine in the off-trade	12,276	36%	35%

[6] The distribution presented in Graph 3C excludes unclassified households because the LCF contains a high proportion (around 40%) in this category. This is due to a higher error rate in responses in the LCF than in the Census.

	This paper		2010 study
	Frequency	Proportion of sample	Proportion of sample
Households consuming cider	4,128	12%	9%
Households consuming cider in the on-trade	1,944	6%	4%
Households consuming cider in the off-trade	2,691	8%	5%
Households consuming spirits	8,071	24%	26%
Households consuming spirits in the on-trade	4,110	12%	15%
Households consuming spirits in the off-trade	4,901	14%	14%
Households consuming RTDs	1,275	4%	9%
Households consuming RTDs in the on-trade	645	2%	6%
Households consuming RTDs in the off-trade	702	2%	4%

Table 3B shows descriptive statistics for household characteristics and attitudes. The ONS weighted average expenditure for the period (in 2009 Q3 prices) is around £405 a week; the small difference compared to the dataset can mainly be attributed by the under-representation of London in the sample and the over-representation of Northern Ireland (the former has the highest weekly expenditure in the country and the latter one of the lowest). In terms of attitudes, the proportion of smoking households in the sample is close to numbers from Action on Smoking and Health (between 21% and 23% over the sample period). Table 3B also contains information on the proportion of households not consuming pork, one of the variables we discuss further in section 4.2.

Table 3B: Descriptive statistics from the dataset on characteristics and attitudes

Characteristics	Mean
Household size	2.4
Weekly expenditure	£393

Attitudes	Proportion of sample
Smoking households	23%
Households not consuming pork	29%

Finally, table 3C gives an overview of (non-inflation adjusted) average prices in the dataset by type of alcohol. Most average prices are in line with market data[7]. The two largest differences - wine and spirits, both in the on-trade – are also those with the largest standard deviation, and so it is natural that the larger variation in price leads to differing average prices in different samples. This is due to wine and spirits having a wider range of prices and quality for the same quantity, as well as a wider range of alcohol by volume content. Our dataset contains does not have enough granularity to allow us to use information on quality or alcohol by volume.

[7] Market data on prices is supplied to HMRC on a regular basis by the ONS.

Table 3C: Alcohol prices in the dataset

Alcohol type	Serving	Nominal price of typical serving (£)	Real price of typical serving (£)	Budget 2012 price (market data, £)
On-trade beer	568ml (pint)	2.92	2.86	2.85
On-trade wine	175ml (glass)	5.01	4.96	3.63
On-trade cider	568ml (pint)	3.27	3.20	3.04
On-trade spirits	25ml (measure)	1.10	1.08	2.07
On-trade RTDs	275ml (bottle)	2.24	2.20	2.53
Off-trade beer	500ml (can)	1.11	1.09	0.89
Off-trade wine	750ml (bottle)	4.73	4.64	4.76
Off-trade cider	500ml (can)	1.06	1.04	0.93
Off-trade spirits	700ml (bottle)	10.63	10.43	11.85
Off-trade RTDs	275ml (bottle)	0.97	0.96	1.14

4. Model specification

4.1. Choosing the model specification

The objective of this study is to understand how demand for different types of alcohol responds to changes in the prices of all the different types of alcohol. This will give us a set of own- and cross-price elasticities of demand for each type of alcohol, which will then be used to estimate behavioural responses to policy changes in alcohol duties. Below we discuss the different decisions that we have made on how to model demand equations and price elasticities of demand.

4.1.1. The decision to use cross-sectional data

The first decision to be made is whether to carry out the modelling in a cross-sectional, time series or panel data framework. A panel framework would the most desirable, so long as the longitudinal sample was representative, as we would able to control for unobserved characteristics that do not vary over time in the sample. Unfortunately, the UK's main longitudinal study, the British Household Panel Survey/Understanding Society, does not have detailed enough data on alcohol expenditure and quantities – the only question currently on the survey related to the theme is on total expenditure on alcohol. Without more detailed data on expenditure by type of alcohol and quantities purchased, a panel approach is therefore not feasible.

For long-run elasticities, a time series approach could feasibly be used, and potentially be more informative than a cross-sectional approach. However, there are a number of reasons why we believe that cross-sectional estimates are more useful for our purposes.

Our costings model works on a rolling five-year basis, and so the effects the elasticity estimates will apply to are relatively short-term. As alcohol prices are now significantly higher than they used to be, estimates derived from the most recent years will also be more relevant when identifying effects for the next few years. Cross-sectional data contains a lot more variation in price, as it allows for variation within time periods. This increases the likelihood of identification of parameters in the model – in this case, the elasticities we are looking for. Cross-sectional datasets are much larger than their time series counterparts too, meaning that it is possible to break the data down into different categories further in cross-sectional data. For all these reasons, and due to the availability of the LCF, which contains very detailed information on household characteristics and alcohol purchases and prices, we have chosen a cross-sectional approach.

4.1.2. Choice of time period to use in the analysis

For our analysis, we use LCF data from 2007 to 2012, whereas the most recent HMRC study, Collis et al (2010), used data from 2001-02 to 2006.

The choice to include only data from 2007 onwards rather than from 2001-02 is due to major changes in the market and in government policy since 2007. 2007 saw the implementation of the indoor smoking ban and from 2008 duties on alcoholic products increased above RPI-measured inflation by 2 percentage points, meaning that price levels since then have become much higher than they were before. These duty changes have generated price variation that allows behavioural responses to be observed. As we will use these elasticity estimates to model the impact of duty rate changes, it is particularly useful to base the estimates on data which shows responses to previous duty rate changes. Wine has also been increasing in popularity since 2007, having overtaken beer to become the largest source of alcohol duty receipts for HMRC at a time when duty rates on wine and beer increased at the same pace.

The LCF was run in financial years until 2005-06, after which it was run in calendar years. This, in combination with the major changes in the market and policy, makes 2007 a natural starting point for analysis, as this was the first full calendar year running of the survey.

4.1.3. Limitations of our dataset

Despite the desirable characteristics, there are several limitations inherent to using cross-sectional datasets and the LCF dataset in particular. The first limitation is the fact that the survey is run on a household level, which means we are unable to capture differences in consumption and preferences within households.

In addition, participation in the LCF is self-selected, that is, of the 12,000 households that are surveyed every year, the ones that actually respond to it are not random – especially because the survey is relatively time-consuming. This means that there are unobserved characteristics that make a household more likely to complete the survey, and the fact that we do not have data on the non-compliant households means that we have no way of assessing the impact of these differences. We would assume that heavy drinkers are often missing from survey data on alcohol consumption.

There is also a question of general under-reporting. Individuals tend to report lower than actual consumption of alcohol, for a number of reasons ranging from genuine mistakes to social taboo. In the same vein, individuals tend to over-inflate their income and qualifications.

4.1.4. Zero observations and Ordinary Least Squares

There is a particular problem in this dataset that needs to be addressed, which is the very high number of zero observations. Just over a third of all households report no consumption of any type of alcohol, while no individual type of alcohol has positive consumption in over 50% of households. Zero observations of alcohol consumption can be due to a number of reasons:

- Consumers being priced out of consuming that type of alcohol;
- Religious, cultural or lifestyle reasons for not consuming alcohol;
- Under-reporting due to social taboo or age restriction;
- Measurement error (either by the respondent or in the processing of the data).

A large number of zero observations means that using Ordinary Least Squares – OLS, the baseline regression methodology, with no correction for bias in the sample – estimates would be inconsistent and biased. Applying OLS only to positive observations does not solve the problem, and would in all likelihood make things worse by introducing selection bias – in effect we would be estimating the combined effect of drinking and of a change in price rather than the effect of a change in price.

There are a number of different approaches that can be used to correct for this bias in the sample. We have chosen to use a Heckman correction, a tried-and-tested form of dealing with the problems inherent to the LCF dataset.

4.1.5. The Heckman correction model

The Heckman correction model was first proposed by Heckman in 1976 and 1979 and treats the censoring of observations as an omitted variables problem. Thus, if we can write out the "rule" or condition that makes individuals more or less likely to be in the sample, we can put this into the equation, which means that the sample selection variable will no longer be omitted.

The model therefore has two equations: a participation equation, in which we estimate the probability that a certain individual has a non-zero observation – in this case, whether a household consumes a type of alcohol or not; and a quantity equation, in which we estimate the quantity for individuals with non-zero observations – in this case, given that a household consumes a certain type of alcohol, how much it consumes – and which includes the bias factor as an explanatory variable.

The equations of the Heckman model can be written as follows:

$$d_i = w'_i \gamma + e_i$$
$$y_i = x'_i \beta + u_i$$

Let $d_i = 1$ if participation occurs and zero otherwise. Then the data is truncated, $E[u_i | d_i = 1] \neq E[u_i] = 0$ and $E[y_i | x_i, d_i = 1] = x_i \beta + E[u_i | d_i = 1]$. This shows that the Heckman correction model treats selection bias as an omitted variables problem, because if we can put the variable causing the bias into the equation, the bias would be corrected.

The solution proposed by Heckman (1976) is to write out the determinants of d_i and estimate the bias factor. It is possible to prove that doing this will solve the selection bias problem using the following property of the truncated normal distribution: if $X \sim N(\mu, \sigma^2)$ and a is a constant, then $E[X | X > a] = \mu + \sigma\lambda(\alpha)$, where:

- $\alpha = \dfrac{a - \mu}{\sigma}$;
- $\phi(\alpha)$ is the probability density function of the normal distribution;
- and $\lambda(\alpha) = \dfrac{\phi(\alpha)}{1 - \Phi(\alpha)} = \dfrac{\phi(\alpha)}{\Phi(-\alpha)}$, which is the **inverse Mills ratio** or the **hazard function**.

It is possible to show that if we do not include the hazard function in the quantity equation, this will result in biased estimates, specifically:

$$E[y_i | y_i > 0, x_i] = E[x_i ' \beta + u_i | x_i ' \beta + u_i > 0, x_i]$$
$$= x_i ' \beta + E[u_i | x_i ' \beta + u_i > 0, x_i]$$

$$= x_i'\beta + \sigma\ E\left[\frac{u_i}{\sigma}\middle|\frac{u_i}{\sigma} > -\frac{x_i'\beta}{\sigma}\right]$$

$$= x_i'\beta + \sigma\ \frac{\phi\left(-\frac{x_i'\beta}{\sigma}\right)}{1-\Phi\left(-\frac{x_i'\beta}{\sigma}\right)} = x_i'\beta + \sigma\ \frac{\phi\left(\frac{x_i'\beta}{\sigma}\right)}{\Phi\left(\frac{x_i'\beta}{\sigma}\right)}$$

$$= x_i'\beta + \sigma\ \lambda\left(-\frac{x_i'\beta}{\sigma}\right) = x_i'\beta - \sigma\ \lambda\left(\frac{x_i'\beta}{\sigma}\right)$$

The equation above shows that the bias is a function of the inverse Mills ratio, and it is a form of omitted variable bias. Heckman's proposal to solve the selection bias in this case is to estimate the inverse Mills ratio for each observation and include it in the quantity equation, meaning that it will be of the form:

$$y_i = x_i'\beta + \delta\lambda_i + u_i$$

If selection bias is the only source of bias in the equation (assuming all other variation is controlled for), then the estimator of λ will be consistent and unbiased.

The participation equation in the model is a probit, which means that estimation must be by maximum likelihood. The likelihood function is shown below:

$$L = \prod_{y_i=0} 1 - \Phi\left(\frac{w'_i\gamma}{\sigma_d}\right) \prod_{y_i>0} \Phi\left\{\left(w'_i\gamma + \frac{\sigma_{dy}}{\sigma_y^2}(y_i - x'_i\beta)\right)\sqrt{\sigma_d^2 - \frac{\sigma_{dy}^2}{\sigma_y^2}}\right\} \times \frac{1}{\sigma_y}\phi\left(\frac{(y_i - x'_i\beta)}{\sigma_y}\right)$$

It is not possible to solve the likelihood function above analytically in only one step. This means that the model can only be solved iteratively, by full information maximum likelihood (FIML).

Until recently, solving a Heckman model by FIML was computationally demanding. To get around this, Heckman proposed an alternative two-step estimator, estimated by limited information maximum likelihood (LIML), which is consistent but generally not as efficient as FIML. However, this is no longer necessary, as FIML is now possible given the increase in computing power. The Heckman FIML estimator was found to generally perform better than the two-step LIML estimator in large samples, although neither performed particularly well in small samples. As the LCF dataset contains over 34,000 observations, it is significantly above the threshold for a large sample, and so we would not expect small sample problems to arise in our study.

The Heckman correction model is formally identified even if there are no exclusion restrictions – that is, even if there are no variables in w that are not present in x – as identification comes from the non-linearity of the inverse Mills ratio. However, the model often performs poorly in the absence of at least one exclusion restriction, especially in finite samples. An exclusion restriction is a variable that is included in the participation equation but not in the quantity equation – essentially an instrument, the term which we use to refer to it in the remainder of the paper.

4.2. Instruments and control variables

While it is theoretically possible to estimate a Heckman correction model without instruments, the estimators are likely to perform poorly in their absence because of severe multicollinearity. It is therefore important we explore variables that can potentially serve as instruments. These instruments should be variables that are uncorrelated with the error term in the quantity equation. In other terms, it can only influence the dependent variable in the quantity equation through the outcome variable of the participation equation. In this case, the instrument can only influence the decision of whether to drink a type of alcohol or not, which in turn influences the decision of how much to consume of that type of alcohol or not; the instrument cannot directly influence the amount the consumer decides to drink.

In addition, ideally these instruments should have a strong enough relationship with the outcome variable of the participation equation so that they are relevant to the decision to participate. In this case, the instrument has to be relevant for the decision of whether to drink a type of alcohol or not. If the relationship is weak, then this could introduce further bias and inconsistency.

In the following section, we go through the instruments we have selected and the reasoning for using them, as well as why we believe they satisfy these conditions.

4.2.1. Instruments selected

There are many reasons for abstaining from alcohol, but most fall into one of four categories: **cultural**, **health** or **religious** reasons or personal **preference** (dislike of drinking alcohol at all or of a particular alcoholic drink).

As we are modelling the decision of whether to drink a particular type of alcohol or not in each of the equations, one of the instruments we use for whether a household consumes a particular type of alcohol is **whether it consumes other types of alcohol**. This is modelled by using dummy variables, which capture both **cultural** and **personal preferences**. Someone who drinks alcohol anyway is more likely to drink any type of alcohol, and putting in dummies for different types of alcohol would allow us to capture the fact that some types of alcohol are more directly linked with one another. For example, drinking beer in the off-trade is likely to be strongly linked with drinking beer in the on-trade; drinking spirits might be related with drinking wine as well; and so on.

The participation equation of the Heckman correction model is estimated using a probit model, meaning that the use of dummy variables as instruments captures information regarding the likelihood of households consuming different types of alcohol together. The dummies also capture this in an intuitive format – it is simple to transform the coefficient on the consumption of a particular drink into a probability of consuming it – and gives us insight into what types of alcohol consumers see as being related to one another[8].

Religion is one of the main reasons for not drinking. A number of religions prohibit or restrict alcohol consumption. Clearly the relationship is not one-to-one – some people adhere more strictly to these proscriptions – but we would expect a strong correlation between following a religion that prohibits alcohol consumption and actually abstaining.

Our dataset contains no direct information on religion. However, it does contain information that allows us to create potential markers for religions which discourage or prohibit alcohol consumption. There is an important overlap between religious groups who do not drink and other dietary guidance based on religion, particularly the prohibition of eating pork, even if the correlation is not perfect. For people who do drink, on the other hand, there is no reason to believe that not eating pork is correlated in any way with the amount that they drink.

[8] Preferences were captured differently in Collis et al (2010), where a constructed variable – 'drink prevalence', calculated as the sum of all different types of alcohol consumed by a household divided by its size – was used as an instrument. We have opted for dummy variables instead as they provide us with more transparent and intuitive results.

Therefore, we have used **not eating pork as an instrument for whether a household drinks a type of alcohol**.

And finally, **health consciousness** is another potential reason for abstaining. However, we find that potential markers for health consciousness are correlated not only with the decision to drink but also with the quantity consumed, and therefore include them as controls rather than as instruments. We discuss these further in section 4.2.2.

One reason for not drinking that is usually put forward is pregnancy, as alcohol intake for pregnant women is discouraged by doctors. Although data on pregnancy is available, unless the household in question is composed exclusively of an expectant mother, this will not manifest itself in our dataset, as it is collected at a household level. We have therefore opted to not include this variable in our study.

4.2.2. Control variables

To isolate the effect of price on quantity, we need to build some controls into the regression equations. If adequate control variables are not present, then we would risk omitted variable bias, meaning that the coefficients on the price variables estimated would also capture the effects of these control variables. The sign of the bias depends on whether the correlation between the regressors and the omitted variables is positive or negative.

We have included a number of standard controls in the regression equations which may cause differences in preferences, such as:

- A **time trend** to control for changes in preferences over time;
- **Regional** differences, for which we have used the nine regions of England, Scotland, Wales and Northern Ireland;
- **Socio-economic group** as defined by skill level of the head of the household;
- **Ethnicity**, as drinking habits vary across different ethnic groups, both in terms of types of alcohol and quantities consumed.

In addition to the variables mentioned above, there are a number of other important factors to control for. **Real income** is one of these, as higher income makes alcohol more affordable, everything else constant. The relationship is unlikely to be linear, as we would expect that differences in income have a larger influence in affordability at the bottom end of the income distribution than at the top end, which is why we model a logarithmic relationship[9]. This reflects the fact that higher income households are likely to buy higher quality and more expensive drinks rather than necessarily larger quantities.

Although income is reported in the LCF, we have chosen to use **total real expenditure** instead as a proxy for income, adjusting nominal expenditure using CPI to account for inflation over time. There are two main reasons for us to choose expenditure over income:

- Income tends to fluctuate more than expenditure; this is the idea behind the permanent income hypothesis, which says that people consume according to what their assessment of their permanent income is rather than according to their current income.

[9] It is worth noting that introducing a measure of income in logs on the right-hand side of the quantity equation with a log variable on the left-hand side will allow us to get a direct estimate of the income elasticity of demand for each type of alcohol. Since alcohol is a normal good, we would expect this estimate to be positive, which is what we find (see Annex 3 for more details).

- Income is often mis-reported in surveys. This is true both in terms of coverage – individuals tend to report money income instead of all income, including benefits in kind, tax breaks, transfers from the government, among others – and in term of bias – individuals on low incomes are more likely to over-report their income, while individuals on high incomes are more likely to under-report their income. By contrast, self-reporting of expenditure usually presents with less problems of this kind.

To capture the impact of income on the affordability of alcohol, we have made an adjustment to the expenditure variable we are using. This is meant to capture both the fact that higher income increases the affordability of alcohol, while at the same time a higher number of people in a household will mean that, for the same level of income, there is less disposable income per head. For **equivalisation of expenditure** across households of different sizes, we have followed recent OECD practice of using the **square root scale**[10].

In addition to the indirect effect of **household size** on the affordability of alcohol, there is also a direct effect on consumption – more people (particularly of drinking age) will lead to a higher level of purchases of alcohol, all else equal. In order to control for this effect, we include a variable to account for the **number of people of drinking age in each household**[11].

One important marker for health consciousness is whether a person **smokes** or not. It has been argued (Wardle and Steptoe, 2003) that it is possible that smokers also have other attitudes that are correlated with poor health, and there is also a culture of drinking and smoking at the same time. As we find smoking to be correlated with both the decision to drink and the quantity consumed, we have included this variable as a control. We also control for elderly households – in particular those composed **exclusively of individuals over 75 years old** – as they are both less likely to drink and drink smaller quantities overall, as confirmed by our results. Finally, we control for **consumption of particularly high-priced and luxury products**, namely sparkling wine, fortified wine and spirits with no mixers, which are likely to have behavioural responses that are different from the wider category.

4.3. The regression equations

For the estimation of the Heckman correction model, we have opted for a double log specification, which means that we are estimating an isoelastic demand model, as standard in econometric practice. An isoelastic demand system is linear in the logs of quantities and the logs of prices, meaning that the elasticity is constant along the demand curve. The main advantage of this specification is that it allows us to directly obtain elasticity estimates with no transformation required; the elasticity estimates are the estimates of the coefficients of the model. There are a number of alternative specifications of the model which could be estimated instead – linear, log-linear and linear-log. In each of these cases, the price elasticity of demand is not constant; rather, it changes along the demand curve, depending on the level of quantity purchased and price. These alternative specifications are explored in the robustness checks in section 6.

Table 4A shows the list of variables used in our final specification. Equations 4A and 4B show the participation and quantity equations estimated for each type of alcohol (denoted by i)

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[10] Equivalisation of incomes using the square root scale consists of dividing total household income by the square root of the size of the household. The OECD technical note is available at http://www.oecd.org/els/soc/OECD-Note-EquivalenceScales.pdf (retrieved 1st July 2014).

[11] Legal drinking age is defined as 16 or above, as drinks can legally be purchased for 16-year-olds in both the on- and the off-trade. Detail on the legislation is available at https://www.gov.uk/alcohol-young-people-law (retrieved 2nd July 2014).

and each household (denoted by j) in matrix format, with the variables aligned in matrices as per the headings in table 4A. The dependent variable in the participation equation is d_{ij}, which takes a value of 1 if household j drinks type of alcohol i and 0 otherwise. λ denotes the inverse Mills ratio, as defined in 4.1.5.

Table 4A: Variables used in final specification

Dependent variables (Q_j)	Explanatory variables (P_j)	Instruments (Z_j)[12]	Controls (X_j)
Quantity of beer (on-trade)	Price of beer (on-trade)	Consumption of beer (on-trade)	Consumption of sparkling wine (on-trade)
Quantity of wine (on-trade)	Price of wine (on-trade)	Consumption of wine (on-trade)	Consumption of sparkling wine (off-trade)
Quantity of cider (on-trade)	Price of cider (on-trade)	Consumption of cider (on-trade)	Consumption of fortified wine (on-trade)
Quantity of spirits (on-trade)	Price of spirits (on-trade)	Consumption of spirits (on-trade)	Consumption of fortified wine (off-trade)
Quantity of RTDs (on-trade)	Price of RTDs (on-trade)	Consumption of RTDs (on-trade)	Consumption of spirits with no mixer (on-trade)
Quantity of beer (off-trade)	Price of beer (off-trade)	Consumption of beer (off-trade)	Consumption of spirits with no mixer (off-trade)
Quantity of wine (off-trade)	Price of wine (off-trade)	Consumption of wine (off-trade)	Smoking household
Quantity of cider (off-trade)	Price of cider (off-trade)	Consumption of cider (off-trade)	Number of people of drinking age
Quantity of spirits (off-trade)	Price of spirits (off-trade)	Consumption of spirits (off-trade)	Household members all over 75 years old
Quantity of RTDs (off-trade)	Price of RTDs (off-trade)	Consumption of RTDs (off-trade)	Log equivalised real expenditure
		No pork consumption	Time trend
			Region
			Socio-economic group
			Ethnicity

Equation 4A: Participation equation in the final specification

$$d_{ij} = Z_j \,.\, \pi_i + \log P_j \,.\, \psi_i + X_j \,.\, \varphi_i + \varepsilon_{ij}$$

Equation 4B: Quantity equation in the final specification

$$\log q_{ij} = \log P_j \,.\, \beta_i + X_j \,.\, \gamma_i + \delta_i \,.\, \lambda_{ij} + u_{ij}$$

As discussed in 4.1.5, this Heckman correction model was estimated by FIML with robust standard errors in order validate statistical inference.

[12] To ensure that no equation suffers from problems of perfect collinearity, we do not apply consumption of a particular type of alcohol as both a dependent variable and an instrument in any of the cases.

5. Estimation results

5.1. Preferred elasticity matrix

We present below the elasticities estimated using the chosen model – an isoelastic specification of the Heckman correction model. In this specification, the elasticity estimates are obtained directly from the model, as they are coefficients to be estimated.

As table 5A shows, all our estimates of own-price elasticities of demand are statistically significant for conventional levels. We also estimate a number of significant cross-price elasticities of demand, generally of lower magnitude than the own-price estimates. We discuss these in more detail below. The regression coefficients and their individual significance are shown in annexes 1 and 2.

Table 5A: Elasticity estimates using the preferred (isoelastic) specification

	Quantity	Beer		Spirits		RTDs		Cider		Wine	
Price		**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**
Beer	**On**	-0.34***	0.03	0.26***	0.08	0.08	0.11	0.05	0.11	0.10*	-0.04
	Off	-0.08	-0.74***	-0.10	-0.11**	0.02	-0.01	-0.02	0.07	-0.02	-0.08*
Spirits	**On**	-0.10***	-0.01	-1.25***	0.01	0.04	0.00	0.00	0.03	0.01	0.05*
	Off	0.00	0.04	-0.16**	-0.45***	-0.22	-0.09	-0.06	0.13	-0.01	-0.02
RTDs	**On**	0.00	0.09	0.17*	0.05	-0.24*	-0.03	-0.02	0.00	-0.04	0.00
	Off	0.00	-0.03	-0.03	-0.02	-0.03	-0.52***	0.03	-0.04	0.04	-0.03
Cider	**On**	-0.06	0.05	0.04	0.10	-0.04	0.24	-0.49***	-0.13	0.02	-0.06
	Off	-0.06	-0.01	0.02	0.05	0.30*	0.13	-0.25**	-0.74***	-0.04	-0.09**
Wine	**On**	0.02	0.02	0.12***	0.00	-0.07	0.01	0.07	-0.04	-0.24***	0.02
	Off	0.01	0.00	-0.02	-0.07*	0.14*	0.10	0.15*	0.05	0.03	-0.08***

*** p<0.05, ** p<0.01, *** p<0.001**

5.2. Discussion of the results

Our own-price estimates suggest that all types of alcohol are price inelastic with the exception of on-trade spirits (-1.25). The next most elastic estimates in our results are for off-trade beer and off-trade cider (-0.74 for both). At the other end of the spectrum, off-trade wine (-0.08), on-trade wine and on-trade RTDs (-0.24 for both) are the least elastic estimates.

In terms of relationship between the on- and off-trade, the results are in line with what we would expect. Like Collis et al (2010) and Meng et al (2014), we find beer, cider and RTDs to be more price elastic in the off-trade, while spirits and wine are more price elastic in the on-trade than in the off-trade. As expected, own-price elasticities are generally estimated to be of a larger magnitude than cross-price elasticities.

5.2.1. Own-price estimates for beer

The own-price estimate for beer in the on-trade (-0.34) is less elastic than the literature median (-0.4), whereas the estimate for the off-trade (-0.74) is more elastic than the median. Both are, however, well within the range of historical estimates. A more elastic estimate for the off-trade than the on-trade is consistent with previous HMRC studies – Huang (2003), Collis et al (2010) and the estimates currently used in HMRC policy costings – as well as external estimates such as Meng et al (2014). This is consistent with off-trade consumption being more driven by price, while social factors are also relevant for consumption decisions in the on-trade.

5.2.2. Own-price estimates for spirits

On-trade spirits are estimated to be the most price elastic of all types of alcohol (-1.25), and it is the only alcohol type we find to be price elastic. Off-trade spirits, meanwhile, are found to be less price elastic (-0.43). Both spirits own-price elasticity estimates are within the literature range. The on-trade own-price estimate is close to previous HMRC estimates – Huang (2003) and Collis et al (2010) – but more elastic than the Meng et al (2014) estimate.

The off-trade own-price estimate is less elastic than the Collis et al (2010) estimate, but as mentioned previously, still well within the literature range. On the other hand, it is considerably more elastic than the Meng et al (2014) estimate.

There are very few studies that look at the price responsiveness of spirits consumption in the off-trade. Most studies consider spirits consumption as a whole; our study finds on-trade spirits to be much more price elastic, meaning that studying them together would generate an estimate somewhere between the on- and off-trade elasticity estimates.

5.2.3. Own-price estimates for RTDs

Our estimate for the own-price elasticity of on-trade RTDs is -0.24. RTDs are the least consumed of all alcohol categories considered in our study, which explains why this is the only own-price elasticity estimate that is only statistically significant at the 5% level rather than 0.1% for all other alcohols. We estimate the own-price elasticity of off-trade RTDs to be -0.52, significant at the 0.1% level.

As RTDs are a small proportion of the market, there are very few studies that estimate elasticities for these types of alcohol. Our estimates suggest that RTDs are less price elastic than Collis et al (2010); however, they are close to the estimates in Meng et al (2014).

5.2.4. Own-price estimates for cider

We estimate own-price elasticities for cider of -0.49 in the on-trade and -0.74 in the off-trade. The finding that off-trade cider is more price elastic than its on-trade counterpart is not surprising, and it is corroborated by both the 2010 study and Meng et al (2014). However, unlike the two aforementioned studies, we find that off-trade cider is price inelastic.

5.2.5. Own-price estimates for wine

We estimate that wine is overall the least price elastic type of alcohol, with own-price elasticity estimates of -0.24 in the on-trade and -0.08 in the off-trade. Inelastic estimates are consistent with substantial growth in wine consumption in the UK, reflecting a shift in preferences towards wine.

The on-trade wine estimate is within the literature range, although closer to the least elastic estimates and certainly less elastic than the literature median. The off-trade estimate is less elastic than all other published estimates considered in the literature review, although most studies only look at wine as a whole and focus on earlier periods. An overall wine elasticity estimate using the same data and specification as this study would be around the least elastic estimate published – Duffy (2002).

The very inelastic estimate for off-trade wine is a result of various factors. One of them is the fact there is much larger variation in price in this type of alcohol than in all other types. This reflects not only general price variation across locations and establishments, but also a wide range in terms of quality that is not reflected in detail in our dataset, which only contains the amount of wine purchased.

We are able to partially control for different preferences in terms of quality by making use of variables such as income and level of qualification, although the cross-sectional nature of the dataset means that some unobserved heterogeneity will remain. However, because alcohol duties are levied on a specific basis, we are more concerned with the overall quantity consumed rather than changes in price. This means that people can respond to changes in prices by trading up or down in quality of wine without a change in quantity consumed. Given this and the robustness checks to this estimate conducted and discussed in 6.4, we are confident that this elasticity estimate is an accurate reflection of consumer responses.

5.2.6. Cross-price estimates

Due to the nature of our modelling, which uses uncompensated or Marshallian demands – that is, incorporating both the income and substitution effect[13] – cross-price effects in our elasticity matrix are not symmetric. For example, we find beer in the on-trade to be an uncompensated complement for beer in the off-trade, while the results suggest that beer in the off-trade is an uncompensated substitute for beer in the on-trade.

This would not be true if we were using compensated or Hicksian demands, which strip out the income effect and only look at the substitution effect; according to standard demand theory, the latter must be symmetric. However, the former does not have to be symmetric, which means that even though the compensated cross-price elasticity would be the same in both cases, the uncompensated cross-price elasticities can have opposite signs due to the strength and direction of the income effect relative to the substitution effect.

We have used uncompensated demands because the objective of our modelling is to provide elasticity estimates to estimate the full consumption effect – including the income effect – of price changes to alcohol products. For the reasons presented above, this means that direct interpretation of cross-price elasticities does not capture the nuances of the effects contained in each. The differences in income effect across types of alcohol will be due to the relative levels of consumption of each household, its income level and preferences, among others, which we do not attempt to isolate. It is worth noting, however, that cross-price effects in our elasticity matrix are almost universally smaller in absolute magnitude than own-price effects, meaning that differences in income effect broadly offset each other across the sample.

6. Robustness checks and alternative specifications

To test the robustness of the results to the specification of the model, we have tested a number of alternative specifications. These include discussion of the strength of the instruments, running OLS regressions on both all and non-zero observations, as well as alternative specifications of the Heckman correction model, alternative control variables and different time periods, among others.

6.1. Performance of instrumental variables

The consistency of the estimator used to obtain the elasticity estimates relies on the instruments having explanatory power. As mentioned in section 4.3, we use an overidentified model, with more than one instrument used to estimate the inverse Mills ratio. The instruments used were dummy variables to capture consumption of other types of alcohol and no consumption of pork by the household.

Generally, for each type of alcohol in the on-trade, the consumption of the same type of alcohol in the off-trade proved highly significant in the participation equation. The converse was also true – consumption in the on-trade was shown to be a strong in determining consumption in the off-trade – while no consumption of pork is highly correlated with alcohol consumption the off-trade. Full details on the regression outputs for the participation equation, including the instruments, are available in Annex 4.

[13] In this framework, the income effect is the change in consumption due to a change in real income from a change in the price of a good, whereas the substitution effect is the change in consumption due to a change in the relative prices of two or more goods.

6.2. Ordinary Least Squares

The first benchmark of a model is whether its predictions are different from those that can be obtained using a basic OLS model. If there are no substantial differences between using an OLS regression and a more complicated model, the argument for using the more complicated model is substantially weakened.

Using an OLS regression in this particular context – with a very large number of zero observations – means that its assumptions will be strong and unlikely to hold. In this case, the implicit assumption is that zero observations are due to the price of alcohol being too high, that is, all zero observations come from potential drinkers, with no allowance for abstinence for non-price reasons.

Table 6A: Elasticity estimates using OLS

	Quantity	Beer		Spirits		RTDs		Cider		Wine	
Price		**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**
Beer	**On**	-0.96***	0.09*	0.12***	0.01	-0.01	0.01	-0.01	0.05*	0.33***	0.05
	Off	0.00	-1.54***	0.01	-0.03	0.00	-0.02	-0.01	-0.10***	0.08***	0.22***
Spirits	**On**	-0.01	0.00	-0.93***	0.00	-0.01**	0.00	-0.01	0.00	0.13***	0.00
	Off	0.03	0.02	-0.08***	-0.92***	-0.01**	-0.03*	0.01	-0.05	0.08**	0.02
RTDs	**On**	0.04	0.01	0.01	0.00	-0.02**	0.01	-0.02	0.02	0.01	0.07
	Off	0.00	-0.01	0.03*	-0.03***	0.00	-0.04***	0.00	0.04*	0.05**	0.03
Cider	**On**	0.01	-0.06	0.13***	0.01	-0.02*	-0.01	-0.21***	-0.01	0.01	0.01
	Off	0.01	0.00	0.10***	0.02	0.01*	0.01	-0.01	-0.61***	0.03	0.04
Wine	**On**	-0.01	0.04*	0.13***	0.04***	0.00	0.00	-0.01*	0.03**	-0.47***	0.04
	Off	-0.02	0.02	0.02	-0.02	0.00	-0.01	0.01	-0.04**	0.11***	-1.04***

*** p<0.05, ** p<0.01, *** p<0.001**

As can be seen by comparing table 6A with table 5A, OLS estimates differ quite significantly from the results obtained using a Heckman correction model. In particular, beer and wine own-price estimates are much more elastic using OLS, as is the own-price estimate for off-trade spirits. The remaining estimates are less elastic, with particularly inelastic estimates for RTDs, likely due to the small number of non-zero observations attenuating the estimates.

Whether OLS results intuitively should be more or less elastic than estimates from the Heckman correction model depends on the particular mix of individuals drinking for price and non-price reasons. Overall, the fact that they are different gives us confidence that the OLS results are likely to be biased and the use of the Heckman provides more consistent estimates.

6.3. Sub-sample OLS

One of the alternative specifications suggested in the literature as an alternative to Heckman is running sub-sample OLS on the uncensored observations. In this context, uncensored observations are non-zero consumption observations.

There are good theoretical reasons why sub-sample OLS might introduce further bias (see section 4 for further detail on this). As discussed above in the case of straight OLS, zero observations may be due to either the price being too high for a particular household or due to abstinence. The implicit assumption in sub-sample OLS is that all households not consuming would never do so regardless of price, which is unlikely to be true.

Table 6B: Elasticity estimates using sub-sample OLS

	Quantity	Beer		Spirits		RTDs		Cider		Wine	
Price		**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**
Beer	**On**	-0.46***	0.06	0.22**	0.05	-0.01	0.18	0.04	0.18	0.15**	-0.03
	Off	-0.07	-0.99***	-0.15*	-0.10*	-0.02	-0.12	-0.03	-0.03	-0.02	-0.04
Spirits	**On**	-0.05*	-0.01	-1.08***	0.02	-0.03	-0.04	-0.01	-0.01	0.06*	0.01
	Off	0.01	0.04	-0.151*	-0.35***	-0.40**	-0.09	0.02	0.04	0.00	-0.01
RTDs	**On**	0.02	0.07	0.18**	0.05	-0.28**	-0.05	-0.04	0.01	-0.04	0.01
	Off	0.00	-0.04	-0.04	-0.02	-0.01	-0.54***	0.01	-0.01	0.05	-0.02
Cider	**On**	-0.04	0.01	0.04	0.10	-0.10	0.27	-0.61***	-0.18*	0.03	-0.05
	Off	-0.08	-0.04	-0.05	0.06	0.45**	0.16	-0.17*	-0.91***	-0.03	-0.08*
Wine	**On**	-0.01	0.01	0.11***	0.00	-0.11	0.00	0.05	-0.01	-0.36***	0.04
	Off	-0.03	-0.05	-0.03	-0.07**	0.15**	0.12	0.15**	-0.05	0.06	-0.21***

*** p<0.05, ** p<0.01, *** p<0.001**

The results from using sub-sample OLS are quite different from the ones obtained using the Heckman correction model, with more elastic results for all alcohols except spirits. This difference is in all likelihood due to the restrictive assumptions of the model regarding zero observations. Sub-sample OLS implicitly assumes that all zero consumption observations are due to non-price reasons. This isolates the consumption responses, but does not allow for potential drinkers in the sample to choose not to consume due to the prices they face. This introduces bias into the results by mis-specifying the preferences of a subset of individuals currently not consuming. The direction of the difference between sub-sample OLS and Heckman will depend on which subset is dominant in the case of alcohol – the non-drinkers for non-price or price reasons.

6.4. Alternative Heckman specifications

In addition to the isoelastic specification discussed in the preferred elasticity matrix section, we have also tested different combination of the Heckman correction model, with either the left, right or both sides of the regression equations in levels rather than logs. The elasticity matrix for each of the combinations is shown below.

The full information maximum likelihood estimator is not as stable when using levels in the left-hand side of the equation. The linear-log and linear models were therefore estimated using the two-step estimator.

Table 6C: Elasticity estimates using a log-linear Heckman correction model (FIML)

	Quantity	Beer		Spirits		RTDs		Cider		Wine	
Price		**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**
Beer	**On**	-0.60***	0.06	0.15*	0.05	0.04	0.11	0.03	0.24*	0.06	-0.02
	Off	-0.08*	-1.13***	-0.18**	-0.09*	-0.09	-0.12	-0.01	-0.15*	-0.02	-0.05
Spirits	**On**	-0.07**	0.00	-0.76***	0.02	0.02	-0.03	0.00	0.02	0.01	0.03
	Off	0.02	0.04	-0.21**	-0.53***	-0.39*	-0.14	-0.13	0.11	-0.03	-0.02
RTDs	**On**	0.03	0.06	0.17*	0.05	-0.30**	-0.07	-0.08	-0.06	-0.05	0.01
	Off	-0.01	-0.05	-0.03	-0.04	0.01	-0.55***	0.00	0.03	0.02	-0.04
Cider	**On**	-0.04	-0.01	0.00	0.09	-0.09	0.21	-0.46***	-0.14	0.02	-0.05
	Off	-0.06	-0.10*	-0.08	0.03	0.42**	0.03	-0.2*	-1.17***	-0.05	-0.09*
Wine	**On**	0.01	0.03	0.06*	0.01	-0.11	0.01	0.1*	0.00	-0.22***	0.04*
	Off	-0.02	-0.01	0.04	-0.01	0.05	0.13	0.08	0.02	0.01	-0.29***

*** p<0.05, ** p<0.01, *** p<0.001**

Table 6D: Elasticity estimates using a linear-log Heckman correction model (two-step estimator)

	Quantity	Beer		Spirits		RTDs		Cider		Wine	
Price		**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**
Beer	**On**	-0.54***	0.04	0.10	0.04	-0.12	0.02	0.05	0.21	0.20*	0.02
	Off	-0.08*	-0.84***	-0.39*	-0.33*	-0.02	-0.04	0.02	-0.10	-0.06	-0.07
Spirits	**On**	-0.08***	-0.01	-0.84***	0.08	0.18*	-0.02	0.01	0.09	0.03	0.03
	Off	-0.02	0.00	-0.50**	-0.95***	-0.30	-0.01	-0.12	0.06	-0.02	-0.04
RTDs	**On**	0.03	0.15*	0.24	0.19	-0.38	-0.14	0.04	-0.11	-0.07	-0.02
	Off	0.04	-0.06	-0.02	-0.11	-0.03	-0.37***	0.06	0.05	0.06	-0.03
Cider	**On**	-0.07	-0.06	-0.03	0.10	-0.15	0.15	-0.35***	-0.06	0.01	-0.10
	Off	-0.03	-0.15**	-0.21	-0.02	0.52	-0.03	-0.35**	-0.83***	-0.11	-0.08
Wine	**On**	-0.03	0.00	0.05	0.05	-0.08	0.03	0.05	-0.04	-0.30***	0.08**
	Off	-0.03	-0.05	0.05	0.08	0.08	0.09	0.06	-0.04	-0.04	-0.31***

*** p<0.05, ** p<0.01, *** p<0.001**

Table 6E: Elasticity estimates using a linear Heckman correction model (two-step estimator)

	Quantity	Beer		Spirits		RTDs		Cider		Wine	
Price		On	Off	On	Off	On	Off	On	Off	On	Off
Beer	On	-0.41***	0.02	0.03	0.14	-0.11	0.04	0.11	0.16	0.23*	0.01
	Off	-0.10*	-0.70***	-0.20	-0.47**	0.05	-0.01	0.06	0.05	-0.04	-0.09
Spirits	On	-0.11***	0.00	-0.68***	0.06	0.18*	0.02	0.02	0.11*	0.04	0.04
	Off	-0.03	0.02	-0.18	-0.93***	-0.12	0.06	-0.05	0.06	-0.01	-0.04
RTDs	On	-0.01	0.14**	0.12	0.22	-0.31	-0.15	0.07	-0.07	-0.05	-0.02
	Off	0.05	-0.04	-0.02	-0.08	0.00	-0.35***	0.08	0.03	0.09	-0.02
Cider	On	-0.11	-0.03	-0.03	0.17	-0.10	0.14	-0.52***	-0.08	-0.03	-0.11
	Off	-0.06	-0.08	-0.16	0.08	0.46	0.06	-0.36**	-0.55***	-0.06	-0.07
Wine	On	-0.02	0.00	0.08	0.06	-0.07	0.02	0.04	-0.04	-0.45***	0.04
	Off	-0.04	-0.03	-0.03	-0.23*	0.18	0.12	0.15	-0.03	-0.02	-0.12***

*** p<0.05, ** p<0.01, *** p<0.001**

In general, the results tend to corroborate what we find using the isoelastic specification, finding almost all (and in some cases all) types of alcohol to be price inelastic. The two-step specifications, however, tend to produce larger cross-price elasticity estimates than we would expect to observe – for example being, a cross-price elasticity of 0.52 between on-trade RTDs and off-trade cider. On-trade beer and wine tend to be less elastic in the preferred isoelastic specification than in tables 6C to 6E.

The fact that the estimates above are broadly in line with our preferred specification gives us confidence in the robustness of the isoelastic model, while its smaller estimated cross-price responses are generally more in line with what we would expect.

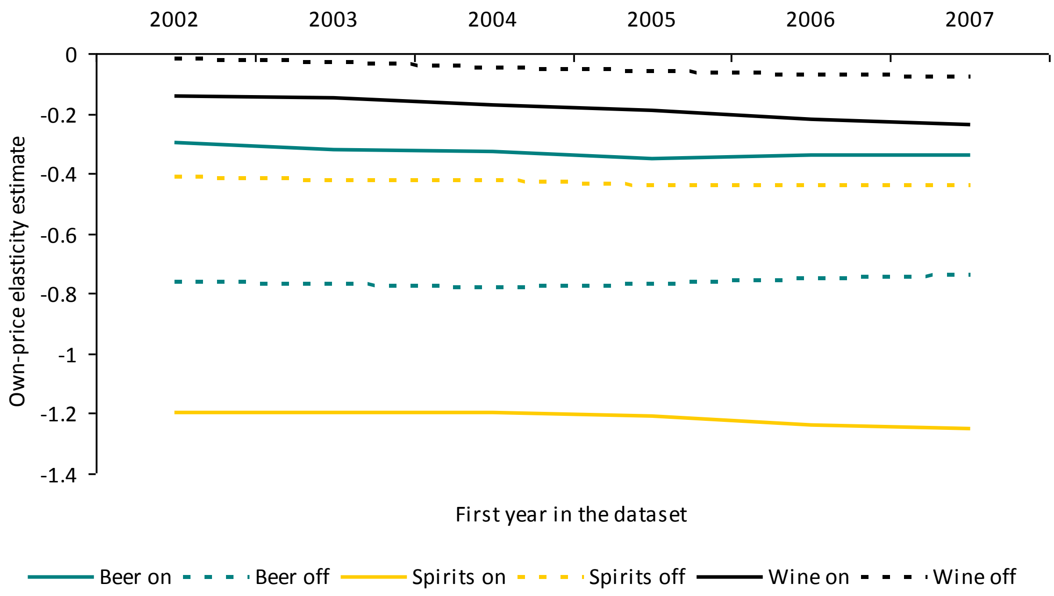
6.5. Other robustness checks

We have tested whether our results are sensitive to the control variables we have used. For example, substituting the time trend in we have used by quarter and year dummy variables instead does not wholly affect results apart from the own-price elasticity estimate for on-trade wine, which has had the most significant growth over the last few years – which also shows itself in the highly significant positive coefficient on the time trend[14]. Controlling for consumption of luxury products – fortified wine, sparkling wine and spirits with no mixers – proved to make a significant difference to the own-price estimates for wine and spirits in the off-trade, making them more elastic and more in line with economic intuition. The results are not very sensitive to the remaining control variables, although we find a number of them to be significant across the different regression equations.

The results proved stable when different time periods were considered. Graph 6A shows the different estimates obtained by using different years as the starting point of the dataset going back to 2002 – the first full calendar year for which LCF data is available – for on- and off-trade in the three main revenue streams (beer, spirits and wine). As can be seen, estimates do not change significantly when different time periods are included, which gives us confidence in the reliability of our preferred estimates presented in table 5A.

[14] See Annexes 3 (quantity equation) and 4 (participation equation) for the full table of regression coefficient estimates and standard errors.

Graph 6A: Own-price elasticity estimates for different starting points in the dataset



It is possible that the estimates for products with higher price variation are being driven towards zero due to it not being possible to differentiate the quality of goods purchased. This is an issue in particular for wine in the off-trade, which presents with very inelastic estimates. This is likely to be due to consumers trading up and down in quality of wine in response to changes in price while holding the quantity purchased constant. We have explored whether we would obtain different elasticity estimates for high, medium and low income households. Neither running separate regressions for each income group nor controlling for them in a combined regression resulted in significantly different estimates. We also explored the possibility of there being different elasticities for smoking and non-smoking households (especially in the on-trade, due to smoking being banned in most on-trade establishments) and by region, but did not find significantly different estimates from running separate regressions in these cases. As these elasticities are intended to estimate the impact on consumption and therefore on alcohol duties – which are specific taxes, and therefore not dependent on price – we believe that the inelastic estimate for off-trade wine is an accurate reflection of the consumer responses.

7. Impact on policy costings

The purpose of estimating this set of own- and cross-price elasticities of demand is to use it as input to estimate Exchequer impacts of changes to alcohol duties. This means that we will be using these elasticities to estimate changes in UK duty-paid consumption, even though they are based on data covering all consumption[15]. The fact that some of the estimates we obtained are more elastic than the literature average is therefore reasonable, as most studies only intend to draw implications for total consumption rather than its subset comprised of duty-paid alcohol.

[15] The data obtained in the LCF is likely to contain purchases of non-UK duty-paid alcohol, although it is unlikely to representatively cover all illicit purchases of alcohol. This is both due to the fact that we expect that not all respondents would register all their illicit purchases and due to the LCF not necessarily providing a representative sample of individuals engaging in illicit activities.

The Exchequer impacts of changes in tax rates are calculated in two steps: a static costing, which keeps the tax base constant and applies a change to the duty rate; and a behavioural costing, in which the percentage change in price from the change in the duty rate is used to calculated the estimated change in consumption, therefore changing the tax base. Own- and cross-price elasticities of demand form the basis of behavioural costings, as they are used to estimate the change in the tax base given a change in duty rates.

The elasticities estimated in this paper will be used for policy costings at future fiscal events, as well as for the Exchequer impacts of illustrative changes in tax rates – "ready reckoners" – published regularly by HMRC and HM Treasury as part of fiscal events. HMRC regularly reviews the elasticities used for its policy costings models; table 7A shows the own- and cross-price elasticity estimates that have been used in policy costings since Budget 2013. The matrix in table 7A was estimated using the same data (2001-2006) and variable selection from Collis et al (2010), but with an updated methodology (Heckman correction model)[16]. To ensure comparability, the figures in subsections below showing the estimated Exchequer impacts of illustrative changes in tax rates for the new and previous elasticities are calculated using the same underlying model, with the only difference being the elasticity matrix used.

Table 7A: HMRC estimates of own- and cross-price elasticities of demand for alcohol – used in HMRC's policy costings from Budget 2013 to Budget 2014

	Quantity	Beer		Spirits		RTDs		Cider		Wine	
Price		**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**
Beer	**On**	-0.44	0.07	0.37	0.04	0.06	-0.02	0.00	0.06	0.09	0.09
	Off	-0.17	-1.07	-0.07	0.02	-0.01	-0.03	0.03	-0.08	-0.08	-0.02
Spirits	**On**	-0.13	-0.03	-1.01	0.00	-0.01	-0.02	-0.01	-0.01	0.01	0.06
	Off	-0.06	-0.02	-0.08	-0.41	-0.01	0.01	-0.10	0.00	-0.01	0.02
RTDs	**On**	-0.09	-0.05	-0.12	0.01	-0.18	0.23	0.05	-0.08	0.20	0.02
	Off	0.01	0.01	0.03	0.02	0.17	-0.57	0.05	0.01	0.07	0.02
Cider	**On**	0.02	0.04	-0.10	0.04	-0.04	0.13	-0.28	-0.07	-0.06	0.00
	Off	-0.01	-0.01	-0.10	-0.03	-0.19	0.02	-0.20	-1.13	0.08	0.02
Wine	**On**	-0.02	0.03	0.09	0.04	-0.02	0.08	-0.08	0.06	-0.24	0.03
	Off	-0.01	0.05	-0.08	-0.01	0.04	0.18	-0.02	0.14	0.08	-0.22

7.1. Exchequer impact of a 1 per cent increase in all alcohol duty rates

Table 7B compares the estimated Exchequer impact of a 1 per cent increase in the duty rate of all alcohols using the current policy costings model and estimates the revenue impact using both the previous elasticities and the new elasticities, rounded to the nearest £5m. Note that although the table shows the impact for an increase in duty rates, the effect expected for a decrease in duty rates is symmetrical.

Table 7B: Exchequer impact of a 1 per cent increase in all alcohol duty rates

All figures £m (rounded to the nearest £5m)	2015-16	2016-17	2017-18
Previous elasticities	+85	+90	+95
New elasticities	+85	+90	+95

As table 7B shows, for small changes in duty rates, the rounded Exchequer impacts of a 1 per cent increase in all alcohol duties are identical. Table 7C summarises the estimated consumption responses for the 1 per cent increase in all alcohol duty rates considered in table 7B. Using the new elasticities estimated in this paper leads to an estimated fall in

[16] See Annex 2 for a more detailed explanation of the estimation procedure used to obtain the elasticity estimates used in HMRC's policy costings since Budget 2013.

consumption for all alcohol products, which is in line with what we would intuitively expect. As with the Exchequer impacts, the consumption responses for a decrease in duty rates would be symmetrical.

Table 7C: Consumption response to a 1 per cent increase in all alcohol duty rates

	Previous elasticities			New elasticities		
Alcohol	**2015-16**	**2016-17**	**2017-18**	**2015-16**	**2016-17**	**2017-18**
Beer						
On-trade	-0.23%	-0.24%	-0.25%	-0.12%	-0.12%	-0.13%
Off-trade	-0.44%	-0.46%	-0.49%	-0.28%	-0.29%	-0.30%
Spirits						
On-trade	-0.22%	-0.23%	-0.25%	-0.26%	-0.27%	-0.29%
Off-trade	-0.26%	-0.27%	-0.28%	-0.35%	-0.36%	-0.38%
RTDs						
On-trade	-0.01%	-0.01%	-0.01%	-0.04%	-0.04%	-0.04%
Off-trade	-0.02%	-0.02%	-0.03%	-0.09%	-0.10%	-0.10%
Cider						
On-trade	-0.13%	-0.13%	-0.14%	-0.05%	-0.05%	-0.05%
Off-trade	-0.22%	-0.23%	-0.24%	-0.02%	-0.02%	-0.02%
Wine						
On-trade	+0.03%	+0.03%	+0.03%	-0.02%	-0.03%	-0.03%
Off-trade	-0.05%	-0.05%	-0.06%	-0.12%	-0.12%	-0.13%

7.2. Exchequer impact of a 1 per cent increase in beer and cider duty rates

At each fiscal event, HMRC publishes the estimated Exchequer impact of an illustrative 1 per cent increase in beer and cider duty rates together, as well as separate estimates for illustrative changes to spirits and wine duty rates. Table 7D compares the estimated Exchequer impacts for a 1 per cent increase in beer and cider duty rates when using the previous elasticities in our policy costings model and using the new elasticity estimates presented in this paper in the same policy costings model, rounded to the nearest £5m. Again, although the table shows the impact for an increase in duty rates, the effect expected for a decrease in duty rates is symmetrical.

Table 7D: Exchequer impact of a 1 per cent increase in beer and cider duty rates

All figures £m (rounded to the nearest £5m)	**2015-16**	**2016-17**	**2017-18**
Previous elasticities	+25	+25	+25
New elasticities	+25	+25	+25

As can be seen from the table, the rounded Exchequer impacts are very similar using the previous elasticities and the new elasticities presented in this paper. However, as shown in table 7E, the reduction in consumption of beer as a response to a change in price is smaller both in the on- and the off-trade, which would lead to small differences in costings of larger changes.

Table 7E: Consumption response to a 1 per cent increase in beer and cider duty rates

	Previous elasticities			New elasticities		
Alcohol	**2015-16**	**2016-17**	**2017-18**	**2015-16**	**2016-17**	**2017-18**
Beer						
On-trade	-0.15%	-0.16%	-0.17%	-0.11%	-0.11%	-0.12%
Off-trade	-0.44%	-0.46%	-0.49%	-0.31%	-0.32%	-0.34%
Spirits						
On-trade	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%	+0.01%
Off-trade	+0.01%	+0.01%	+0.01%	-0.01%	-0.01%	-0.01%
RTDs						
On-trade	-0.04%	-0.04%	-0.04%	+0.09%	+0.09%	+0.09%
Off-trade	0.00%	0.00%	0.00%	+0.06%	+0.06%	+0.06%
Cider						
On-trade	-0.05%	-0.05%	-0.05%	-0.09%	-0.10%	-0.10%
Off-trade	-0.28%	-0.29%	-0.31%	-0.13%	-0.13%	-0.14%
Wine						
On-trade	-0.01%	-0.01%	-0.01%	0.00%	0.00%	0.00%
Off-trade	+0.01%	+0.01%	+0.01%	-0.07%	-0.07%	-0.07%

7.3. Exchequer impact of a 1 per cent increase in spirits duty rates

Table 7F compares the estimated Exchequer impacts for a 1 per cent increase in spirits duty rates when using the previous elasticities in our policy costings model and using the new elasticity estimates presented in this paper in the same policy costings model, rounded to the nearest £5m. Although the table shows the impact for an increase in duty rates, the effect expected for a decrease in duty rates is symmetrical.

Table 7F: Exchequer impact of a 1 per cent increase in spirits duty rates

All figures £m (rounded to the nearest £5m)	2015-16	2016-17	2017-18
Previous elasticities	+20	+20	+25
New elasticities	+20	+20	+20

The rounded Exchequer impacts using the previous elasticities and the new elasticities are similar, although slightly smaller in magnitude with the new elasticities. Table 7G shows this to be the case mainly due to a larger behavioural response from spirits consumers, due to the new elasticity estimates being more elastic than the previous elasticities.

Table 7G: Consumption response to a 1 per cent increase in spirits duty rates

	Previous elasticities			New elasticities		
Alcohol	**2015-16**	**2016-17**	**2017-18**	**2015-16**	**2016-17**	**2017-18**
Beer						
On-trade	-0.06%	-0.07%	-0.07%	-0.01%	-0.01%	-0.01%
Off-trade	-0.02%	-0.02%	-0.02%	+0.03%	+0.03%	+0.03%
Spirits						
On-trade	-0.20%	-0.21%	-0.23%	-0.28%	-0.30%	-0.32%
Off-trade	-0.28%	-0.29%	-0.31%	-0.30%	-0.32%	-0.33%
RTDs						
On-trade	0.00%	0.00%	0.00%	-0.16%	-0.16%	-0.17%
Off-trade	-0.04%	-0.04%	-0.04%	-0.11%	-0.11%	-0.12%
Cider						
On-trade	-0.06%	-0.07%	-0.07%	-0.04%	-0.04%	-0.04%
Off-trade	-0.01%	-0.01%	-0.01%	+0.09%	+0.10%	+0.10%
Wine						
On-trade	+0.01%	+0.01%	+0.01%	0.00%	0.00%	0.00%
Off-trade	+0.02%	+0.02%	+0.02%	-0.01%	-0.01%	-0.01%

7.4. Exchequer impact of a 1 per cent increase in wine duty rates

Table 7H compares the estimated Exchequer impacts for a 1 per cent increase in wine duty rates when using the previous elasticities and the new elasticity estimates in our policy costings model, rounded to the nearest £5m. Although the table shows the impact for an increase in duty rates, the effect expected for a decrease in duty rates is symmetrical.

Table 7H: Exchequer impact of a 1 per cent increase in wine duty rates

All figures £m (rounded to the nearest £5m)	2015-16	2016-17	2017-18
Previous elasticities	+35	+40	+45
New elasticities	+40	+40	+45

As the table above shows, the rounded Exchequer impacts are similar when using the previous elasticities and the new elasticities, although it is slightly larger in the case of the latter than in the former. Table 7I shows the estimates for the consumption response to this increase in duties; in particular, an increase in wine duties is estimated under the new elasticities to lead to a fall in wine consumption in both the on- and the off-trade, which is in line with what we would intuitively expect.

Table 7I: Consumption response to a 1 per cent increase in wine duty rates

	Previous elasticities			New elasticities		
Alcohol	**2015-16**	**2016-17**	**2017-18**	**2015-16**	**2016-17**	**2017-18**
Beer						
On-trade	-0.01%	-0.01%	-0.01%	+0.01%	+0.01%	+0.01%
Off-trade	+0.02%	+0.02%	+0.03%	0.00%	0.00%	0.00%
Spirits						
On-trade	-0.03%	-0.03%	-0.03%	+0.02%	+0.02%	+0.02%
Off-trade	+0.01%	+0.01%	+0.01%	-0.03%	-0.03%	-0.03%
RTDs						
On-trade	+0.03%	+0.03%	+0.03%	+0.03%	+0.03%	+0.03%
Off-trade	+0.01%	+0.01%	+0.01%	-0.04%	-0.05%	-0.05%
Cider						
On-trade	-0.01%	-0.01%	-0.01%	+0.08%	+0.09%	+0.09%
Off-trade	+0.07%	+0.07%	+0.08%	+0.01%	+0.01%	+0.01%
Wine						
On-trade	+0.03%	+0.03%	+0.03%	-0.02%	-0.02%	-0.02%
Off-trade	-0.09%	-0.09%	-0.09%	-0.04%	-0.04%	-0.04%

8. Conclusion

The main objective of this study was to update the own- and cross-price elasticities of demand used by HMRC in its alcohol policy costings model to estimate the behavioural impact of changes in duty rates on Exchequer revenues. To do this, we have applied a Heckman correction model to data from the Living Costs and Food Survey from 2007 to 2012. This model corrects for sample selection, and it is used in order to separate the impact of zero consumption observations due to abstinence and as a response to prices faced.

The new elasticity estimates, presented in table 8A, are in line with economic intuition, and are consistent with existing literature on estimated behavioural responses. All own-price elasticity estimates are highly significant, as are a number of cross-price elasticity estimates.

Table 8A: Elasticity estimates from this paper using the Heckman correction model

	Quantity	Beer		Spirits		RTDs		Cider		Wine	
Price		**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**	**On**	**Off**
Beer	**On**	-0.34***	0.03	0.26***	0.08	0.08	0.11	0.05	0.11	0.10*	-0.04
	Off	-0.08	-0.74***	-0.10	-0.11**	0.02	-0.01	-0.02	0.07	-0.02	-0.08*
Spirits	**On**	-0.10***	-0.01	-1.25***	0.01	0.04	0.00	0.00	0.03	0.01	0.05*
	Off	0.00	0.04	-0.16**	-0.45***	-0.22	-0.09	-0.06	0.13	-0.01	-0.02
RTDs	**On**	0.00	0.09	0.17*	0.05	-0.24*	-0.03	-0.02	0.00	-0.04	0.00
	Off	0.00	-0.03	-0.03	-0.02	-0.03	-0.52***	0.03	-0.04	0.04	-0.03
Cider	**On**	-0.06	0.05	0.04	0.10	-0.04	0.24	-0.49***	-0.13	0.02	-0.06
	Off	-0.06	-0.01	0.02	0.05	0.30*	0.13	-0.25**	-0.74***	-0.04	-0.09**
Wine	**On**	0.02	0.02	0.12***	0.00	-0.07	0.01	0.07	-0.04	-0.24***	0.02
	Off	0.01	0.00	-0.02	-0.07*	0.14*	0.10	0.15*	0.05	0.03	-0.08***

*** p<0.05, ** p<0.01, *** p<0.001**

As with any study of this type, there are a number of limitations and uncertainties. In empirical econometrics, the results are only as good as the data available; while the LCF is the best data source we have available, the fact that it is a cross-sectional survey means that some unobserved heterogeneity remains, as well as some under-reporting usually present in this type of survey. There are also some limitations due to the fact that the data is collected at a household level, which to some extent masks individual preferences and reduces variation in the data.

This revision to HMRC's alcohol price elasticities of demand builds on previous work in HMRC, using new data to better reflect current consumer preferences, as well as updating the methodology and variable selection in line with best practice. It is also in line with HMRC's commitment to keep the assumptions used in its models under continual review. There is scope for future work in updating these elasticity estimates at regular intervals in order to ensure that they are based on the most recent available data. There would also be benefits to obtaining more granular data from longitudinal surveys, which would allow for further controlling for unobserved heterogeneity.

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Annex 1: Constructing the dataset from the Living Costs and Food Survey data

This annex contains detailed information on how the dataset was constructed from the LCF raw data available at UK Data Archive.

A1.1. The Family Food Module

The information on purchases is recorded in a diary, which respondents are asked to keep for two weeks. The survey is conducted across the year rather than at a specific point in time in order to account for seasonal effects. This information on expenditure and quantities allows us to calculate average prices faced by each household during the period they were surveyed.

The expenditure categories in the Family Food Module are not directly aligned with the tax system, which means that we have to aggregate them into the ten categories we want to estimate elasticities for. The manner in which alcohols are aggregated into categories is shown in table A1A. We have excluded the **round of drinks** variable (MAFF code[17] 270401), as the variable does not contain enough information for it to be allocated to a particular type of drink.

Table A1A: Aggregation of LCF category into alcohol types

Alcohol type	Maffcode	LCF category
On-trade beer	270301	Bitters – half-pint or bottle (away from home)
	270302	Bitters – pint, can or non-specified size (away from home)
	270303	Lagers and continental beers – half-pint or bottle (away from home)
	270304	Lagers and continental beers – pint, can or non-specified size (away from home)
On-trade wine	270201	Table wine (away from home)
	270202	Sparkling wine (away from home)
	270203	Fortified wine (away from home)
On-trade cider	270204	Cider or perry – half-pint or bottle (away from home)
	270205	Cider or perry – pint, can or non-specified size (away from home)
On-trade spirits	270101	Spirits (away from home)
	270102	Liqueurs (away from home)
	270103	Cocktails (away from home)
	270104	Spirits or liqueurs with a mixer (away from home)
On-trade RTDs	270206	Alcoholic soft drinks (alcopops) and ready-mixed bottled drinks (away from home)
Off-trade beer	38102	Bitters (brought home)
	38202	Lagers and continental beers (brought home)

[17] MAFF codes were originally used by the then Ministry of Agriculture, Food and Fisheries (currently Defra) to categorise food products. The Family Food Module of the LCF continues to use this classification in order to maintain inter-year comparability of dataset.

Alcohol type	Maffcode	LCF category
Off-trade wine	38402	Sparkling wine (brought home)
	38403	Table wine (brought home)
	38601	Fortified wine (brought home)
Off-trade cider	38302	Cider or perry (brought home)
Off-trade spirits	38501	Spirits with mixer (brought home)
	38701	Spirits (brought home)
	38801	Liqueurs and cocktails (brought home)
Off-trade RTDs	38901	Alcopops (brought home)

A1.2. The main LCF dataset: household-level data

We then match the expenditure, quantity purchased and price of each type of alcohol for each household to the main LCF household-level dataset, using the unique case number of each observation. From the main dataset, we also use a number of household-level variables, which are listed in table A1B.

Table A1B: LCF household-level variables

LCF Code	Variable
A049	Household size
A099	Quarter of survey
Year	Year of survey
P600	Weekly total consumption expenditure (EFS criteria)
Gorx	Government Office Region

In addition, we took the National Statistics SEC 8-class of household reference person variable (A094) as a starting point to create a **socio-economic group of household reference person** variable, aggregating classes as shown in table A1C. The classification of individuals' skills is in line with the classification used in Meng et al. (2014)[18].

[18] Pensioners, where classified, are allocated to different groups according to their skills when they worked, as their consumption is more likely to be linked with their socio-economic group during their working life than with their current status as pensioners.

Table A1C: Socio-economic classification

Socio-economic group	NS-SEC 8 class
High-skilled	Large employers and higher managerial
	Higher professionals
Medium-skilled	Lower managerial and professionals
	Intermediate
	Small employers and own account workers
	Lower supervisory and technical
Low-skilled	Semi-routine
	Routine
Unemployed	Never worked and long-term unemployed
Students	Students
Not classified	Occupation not stated
	Not recorded
	Not classified for other reasons

A1.3. The main LCF dataset: personal data

We also make use of the personal questions on attitudes asked in the LCF. Because the data on expenditure is at household level, we then convert the indicators to household level as the elasticity estimates will be estimated at household level. Table A1D shows how the variables in the personal dataset were converted into household-level variables.

Table A1D: Derived variables from the LCF personal dataset

Variable	Possible values
Smoking	1 if household spends a positive amount on tobacco; 0 otherwise
No Pork	0 if household spends a positive amount on pork, bacon, ham, sausage or offal; 1 otherwise

The final dataset contains 34,326 observations, distributed relatively uniformly across the six years included as per the table A1E. The dataset is also relatively uniform in terms of quarters of the year in which households were surveyed, as shown in table A1F.

Table A1E: Distribution of observations in the dataset across years

Year	Frequency	Percentage	Cumulative percentage
2007	6,131	17.86%	17.86%
2008	5,841	17.02%	34.88%
2009	5,815	16.94%	51.82%
2010	5,258	15.32%	67.14%
2011	5,689	16.57%	83.71%
2012	5,592	16.29%	100%
Total	34,326	100%	

Table A1F: Distribution of observations in the dataset across quarters

Quarter	Frequency	Percentage	Cumulative pct.
January to March	8,440	24.59%	24.59%
April to June	8,517	24.81%	49.40%
July to September	8,791	25.61%	75.01%
October to December	8,578	24.99%	100%
Total	34,326	100%	

The remaining descriptive statistics of the dataset are presented in section 3.4 of the main body of the paper.

Annex 2: Elasticities currently used in HMRC's policy costings model since Budget 2013

A2.1. Changes in methodology from 2010 estimation

Since the last study into alcohol elasticities published by HMRC in 2010, there have been refinements to the elasticity estimates used in policy costings, with a re-estimation being conducted in 2013 using the same data as Collis et al (2010) – EFS data from 2001-02 to 2006 – but the modelling was conducted using a Heckman correction model as in the study in the main body of this paper. The elasticities were estimated Heckman's two-step consistent procedure by limited information maximum likelihood.

A2.2. Variable selection and model specification

No new variables were used in the 2013 re-estimation when compared with Collis et al (2010). The main difference is the fact that the 2013 re-estimation used a two-equation model, with the first equation looking at participation (drinking or not drinking) and the second looking at quantity consumed. The participation equation has two exclusion restrictions: drink prevalence, a constructed variable calculated as the sum of all different types of alcohol consumed by a household divided by its size which had already been used in Collis et al (2010); and the log of non-alcohol expenditure. Table A2A shows the variable selection for the 2013 re-estimation, while equations A2A and A2B show the participation and quantity equations, with the same variable definitions as in 4.3.

Table A2A: Variables used in final specification of the 2013 re-estimation

Dependent variables (Q_j)	Explanatory variables (P_j)	Instruments (Z_j)	Controls (X_j)
Quantity of beer (on-trade)	Price of beer (on-trade)	Drink prevalence	Region
Quantity of wine (on-trade)	Price of wine (on-trade)	Log non-alcohol expenditure	Socio-economic group
Quantity of cider (on-trade)	Price of cider (on-trade)		Year
Quantity of spirits (on-trade)	Price of spirits (on-trade)		Quarter
Quantity of RTDs (on-trade)	Price of RTDs (on-trade)		
Quantity of beer (off-trade)	Price of beer (off-trade)		
Quantity of wine (off-trade)	Price of wine (off-trade)		
Quantity of cider (off-trade)	Price of cider (off-trade)		
Quantity of spirits (off-trade)	Price of spirits (off-trade)		
Quantity of RTDs (off-trade)	Price of RTDs (off-trade)		

Equation A2A: Participation equation in the final specification of 2013 re-estimation

$$d_{ij} = Z_j \,.\, \pi_i + P_j \,.\, \psi_i + X_j \,.\, \varphi_i + \varepsilon_{ij}$$

Equation A2B: Quantity equation in the final specification of 2013 re-estimation

$$\log q_{ij} = \log P_j \,.\, \beta_i + X_j \,.\, \gamma_i + \delta_i \,.\, \lambda_{ij} + u_{ij}$$

A2.3. Results from 2013 re-estimation

Table A2B shows the elasticity estimates resulting from the 2013 re-estimation used in HMRC's policy costings since Budget 2013 and certified by the Office for Budget Responsibility, while table A2C shows the elasticity estimates used prior to that fiscal event and based on Collis et al (2010). The results show own price elasticities to be generally higher than cross-price elasticities in line with the expectation that changes in the price of the product consumed is more influential than prices of other alcohol products. The 2013 estimates suggest relatively smaller behavioural impacts compared to the 2010 estimates. In addition, the re-estimation reduced the number of large negative cross-price elasticities (that suggest different drink types are complements).

Table A2B: 2013 elasticity estimates – used in policy costings since Budget 2013

Price	Quantity	Beer		Spirits		RTDs		Cider		Wine	
		On	Off	On	Off	On	Off	On	Off	On	Off
Beer	On	-0.44	0.07	0.37	0.04	0.06	-0.02	0.00	0.06	0.09	0.09
	Off	-0.17	-1.07	-0.07	0.02	-0.01	-0.03	0.03	-0.08	-0.08	-0.02
Spirits	On	-0.13	-0.03	-1.01	0.00	-0.01	-0.02	-0.01	-0.01	0.01	0.06
	Off	-0.06	-0.02	-0.08	-0.41	-0.01	0.01	-0.10	0.00	-0.01	0.02
RTDs	On	-0.09	-0.05	-0.12	0.01	-0.18	0.23	0.05	-0.08	0.20	0.02
	Off	0.01	0.01	0.03	0.02	0.17	-0.57	0.05	0.01	0.07	0.02
Cider	On	0.02	0.04	-0.10	0.04	-0.04	0.13	-0.28	-0.07	-0.06	0.00
	Off	-0.01	-0.01	-0.10	-0.03	-0.19	0.02	-0.20	-1.13	0.08	0.02
Wine	On	-0.02	0.03	0.09	0.04	-0.02	0.08	-0.08	0.06	-0.24	0.03
	Off	-0.01	0.05	-0.08	-0.01	0.04	0.18	-0.02	0.14	0.08	-0.22

Table A2C: 2010 elasticity estimates – used in policy costings until Autumn Statement 2012

Price	Quantity	Beer		Spirits		RTDs		Cider		Wine	
		On	Off	On	Off	On	Off	On	Off	On	Off
Beer	On	-0.77	-0.06	0.00	0.00	0.00	0.00	-0.09	0.00	0.38	0.06
	Off	-0.10	-1.11	0.00	-0.20	0.00	-0.01	0.00	-0.18	0.09	0.00
Spirits	On	-0.09	0.02	-1.15	0.02	-0.54	0.00	-0.17	0.05	0.00	0.11
	Off	0.00	-0.10	0.00	-0.90	0.00	-0.19	0.00	-0.12	0.03	0.00
RTDs	On	0.00	0.00	0.00	0.00	-0.91	0.00	0.00	0.00	0.05	0.04
	Off	0.00	0.00	0.01	0.00	0.00	-0.93	0.00	0.00	0.00	0.00
Cider	On	0.03	0.09	0.00	0.00	0.00	0.00	-0.85	0.00	0.00	0.00
	Off	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	-1.34	0.16	0.10
Wine	On	-0.01	0.17	0.03	0.27	0.00	0.18	0.00	0.16	-0.46	0.01
	Off	0.00	-0.30	0.00	0.00	-0.27	-0.54	0.00	-0.72	0.00	-0.54

A2.4. Changes in policy costings compared to 2010 elasticities

Table A2D compares the estimated Exchequer impact of a 1 per cent increase in the duty rate of all alcohols using the 2013 and 2010 elasticity estimates, rounded to the nearest £5m. Note that although the table shows the impact for an increase in duty rates, the effect expected for a decrease in duty rates is symmetrical.

Table A2D: Exchequer impact of a 1 per cent increase in all alcohol duty rates

All figures £m (rounded to the nearest £5m)	2014-15	2015-16	2016-17
2013 elasticity estimates	+85	+85	+90
2010 elasticity estimates	+65	+65	+70

As table A2D shows that for similar changes in duty rates, Exchequer impacts are larger under the 2013 elasticity estimates than under the 2010 estimates, which is mostly due to the 2013 estimates suggesting smaller behavioural responses. Table A2E summarises the estimated consumption responses for the 1 per cent increase in all alcohol duty rates considered in table A2D. As with the Exchequer impacts, the consumption responses for a decrease in duty rates would be symmetrical.

Table A2E: Consumption response to a 1 per cent increase in all alcohol duty rates

	2013 elasticity estimates			2010 elasticity estimates		
Alcohol	**2014-15**	**2015-16**	**2016-17**	**2014-15**	**2015-16**	**2016-17**
Beer						
On-trade	-0.23%	-0.24%	-0.25%	-0.19%	-0.20%	-0.21%
Off-trade	-0.45%	-0.47%	-0.50%	-0.66%	-0.70%	-0.74%
Spirits						
On-trade	-0.22%	-0.23%	-0.24%	-0.15%	-0.16%	-0.17%
Off-trade	-0.26%	-0.27%	-0.28%	-0.67%	-0.71%	-0.75%
RTDs						
On-trade	-0.01%	-0.01%	-0.01%	-0.31%	-0.33%	-0.36%
Off-trade	-0.02%	-0.03%	-0.03%	-0.59%	-0.62%	-0.66%
Cider						
On-trade	-0.12%	-0.13%	-0.14%	-0.12%	-0.13%	-0.14%
Off-trade	-0.22%	-0.23%	-0.24%	-0.76%	-0.81%	-0.87%
Wine						
On-trade	+0.03%	+0.03%	+0.03%	+0.10%	+0.10%	+0.10%
Off-trade	-0.05%	-0.05%	-0.05%	-0.19%	-0.19%	-0.20%

Annex 3: Regression outputs for the quantity equation

Table A3A provides the details of the regression outputs for the quantity equation, with the point estimates and standard errors for each coefficient. The quantity equation is the main equation of the study, and because it is estimates in a double log specification, the elasticity estimates are the coefficients obtained from the log prices in the table below.

Table A3A: Point estimates and standard errors from the quantity equation

	Beer on estimate (std. error)	Beer off estimate (std. error)	Spirits on estimate (std. error)	Spirits off estimate (std. error)	RTDs on estimate (std. error)	RTDs off estimate (std. error)	Cider on estimate (std. error)	Cider off estimate (std. error)	Wine on estimate (std. error)	Wine off estimate (std. error)
Log price	-0.338***	0.031	0.258***	0.084	0.080	0.112	0.048	0.105	0.103*	-0.037
of beer (on)	(-0.04)	(-0.05)	(-0.06)	(-0.05)	(-0.13)	(-0.16)	(-0.1)	(-0.09)	(-0.05)	(-0.05)
Log price	-0.077	-0.742***	-0.103	-0.110**	0.022	-0.014	-0.017	0.070	-0.023	-0.083*
of beer (off)	(-0.04)	(-0.03)	(-0.06)	(-0.04)	(-0.11)	(-0.1)	(-0.08)	(-0.06)	(-0.04)	(-0.04)
Log price	-0.101***	-0.006	-1.245***	0.010	0.040	-0.002	-0.003	0.025	0.011	0.046*
of spirits (on)	(-0.02)	(-0.03)	(-0.03)	(-0.02)	(-0.06)	(-0.06)	(-0.04)	(-0.04)	(-0.02)	(-0.02)
Log price	0.002	0.041	-0.162**	-0.445***	-0.218	-0.090	-0.055	0.134	-0.007	-0.021
of spirits (off)	(-0.05)	(-0.04)	(-0.06)	(-0.03)	(-0.13)	(-0.1)	(-0.1)	(-0.07)	(-0.04)	(-0.04)
Log price	0.000	0.088	0.169*	0.049	-0.241*	-0.030	-0.020	-0.003	-0.043	-0.004
of RTDs (on)	(-0.05)	(-0.05)	(-0.07)	(-0.04)	(-0.1)	(-0.12)	(-0.09)	(-0.08)	(-0.05)	(-0.04)
Log price	-0.001	-0.028	-0.034	-0.023	-0.026	-0.521***	0.029	-0.038	0.038	-0.031
of RTDs (off)	(-0.03)	(-0.04)	(-0.05)	(-0.03)	(-0.1)	(-0.06)	(-0.07)	(-0.06)	(-0.03)	(-0.03)
Log price	-0.060	0.051	0.041	0.103	-0.043	0.241	-0.494***	-0.132	0.016	-0.055
of cider (on)	(-0.06)	(-0.06)	(-0.07)	(-0.06)	(-0.15)	(-0.15)	(-0.07)	(-0.09)	(-0.06)	(-0.05)
Log price	-0.056	-0.014	0.015	0.047	0.304*	0.130	-0.249**	-0.742***	-0.044	-0.094**
of cider (off)	(-0.04)	(-0.04)	(-0.06)	(-0.03)	(-0.14)	(-0.1)	(-0.08)	(-0.04)	(-0.04)	(-0.03)
Log price	0.016	0.021	0.115***	0.002	-0.073	0.012	0.069	-0.035	-0.239***	0.019
of wine (on)	(-0.02)	(-0.03)	(-0.03)	(-0.02)	(-0.08)	(-0.07)	(-0.05)	(-0.05)	(-0.02)	(-0.02)
Log price	0.006	-0.004	-0.019	-0.066*	0.143*	0.095	0.152*	0.051	0.028	-0.079***
of wine (off)	(-0.03)	(-0.03)	(-0.04)	(-0.03)	(-0.06)	(-0.08)	(-0.07)	(-0.06)	(-0.03)	(-0.02)
Consumption of	0.049	-0.173*	0.293***	0.074	-0.235	-0.005	0.035	-0.170	0.085	0.029
sparkling wine (on)	(-0.06)	(-0.08)	(-0.07)	(-0.07)	(-0.2)	(-0.23)	(-0.12)	(-0.12)	(-0.05)	(-0.06)
Consumption of	-0.074	0.148**	0.022	0.072	0.078	-0.077	-0.040	-0.081	0.030	-0.046
sparkling wine (off)	(-0.05)	(-0.05)	(-0.06)	(-0.04)	(-0.15)	(-0.12)	(-0.1)	(-0.08)	(-0.04)	(-0.03)
Consumption of	0.085	-0.092	-0.092	-0.231*	0.122	-0.056	0.302	-0.273	-0.558***	-0.038
fortified wine (on)	(-0.09)	(-0.12)	(-0.1)	(-0.1)	(-0.29)	(-0.32)	(-0.18)	(-0.21)	(-0.07)	(-0.09)
Consumption of	-0.106*	0.033	-0.096	0.149***	-0.233	-0.233*	-0.089	-0.174*	0.066	-0.159***
fortified wine (off)	(-0.05)	(-0.05)	(-0.07)	(-0.03)	(-0.2)	(-0.11)	(-0.12)	(-0.07)	(-0.04)	(-0.04)
Consumption of	0.344***	0.010	0.652***	-0.013	-0.002	0.078	-0.112	0.084	0.198***	-0.063
spirits no mixer (on)	(-0.04)	(-0.05)	(-0.07)	(-0.04)	(-0.1)	(-0.12)	(-0.07)	(-0.09)	(-0.04)	(-0.04)
Consumption of	-0.023	-0.027	0.105**	0.800***	-0.043	0.116	0.049	0.012	0.002	0.194***
spirits no mixer (off)	(-0.03)	(-0.03)	(-0.04)	(-0.06)	(-0.08)	(-0.07)	(-0.06)	(-0.04)	(-0.03)	(-0.02)
Smoking	0.277***	0.146***	0.222***	0.056**	0.188**	0.027	0.361***	0.199***	0.070**	0.051*
household	(-0.02)	(-0.02)	(-0.03)	(-0.02)	(-0.07)	(-0.06)	(-0.05)	(-0.04)	(-0.03)	(-0.02)
Number of people	0.047***	0.012	0.094***	0.019	0.023	0.017	0.009	-0.056*	0.018	0.035**
of drinking age	(-0.01)	(-0.01)	(-0.02)	(-0.01)	(-0.04)	(-0.03)	(-0.03)	(-0.02)	(-0.01)	(-0.01)
Household with all	-0.346***	0.041	-0.159	0.004	-0.664	0.036	-0.427*	-0.281**	-0.062	-0.086*
members over 75	(-0.05)	(-0.06)	(-0.09)	(-0.04)	(-0.58)	(-0.18)	(-0.18)	(-0.11)	(-0.05)	(-0.04)
Log real equivalised	0.061**	0.061**	0.244***	0.155***	0.124	0.214***	-0.020	0.082*	0.244***	0.253***
expenditure	(-0.02)	(-0.02)	(-0.03)	(-0.02)	(-0.07)	(-0.06)	(-0.05)	(-0.04)	(-0.03)	(-0.02)
Time	-0.005**	-0.004*	0.000	0.002	-0.012*	-0.003	0.000	-0.004	0.014***	0.001
trend	(0.00)	(0.00)	(0.00)	(0.00)	(-0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
North West and	-0.101	-0.131*	-0.013	0.012	0.112	0.151	0.067	-0.088	0.064	0.037
Merseyside	(-0.06)	(-0.06)	(-0.08)	(-0.05)	(-0.17)	(-0.15)	(-0.12)	(-0.1)	(-0.06)	(-0.05)
Yorkshire and	-0.185***	-0.039	-0.107	-0.057	0.282	0.077	0.012	-0.071	0.006	-0.061
the Humber	(-0.06)	(-0.06)	(-0.09)	(-0.05)	(-0.18)	(-0.16)	(-0.12)	(-0.1)	(-0.07)	(-0.05)
East	-0.229***	-0.176**	-0.155	-0.047	0.091	0.257	-0.006	-0.103	-0.047	0.002
Midlands	(-0.06)	(-0.06)	(-0.09)	(-0.06)	(-0.18)	(-0.16)	(-0.12)	(-0.1)	(-0.07)	(-0.05)
West	-0.180**	-0.205***	-0.022	-0.075	0.059	0.125	-0.103	-0.159	-0.053	-0.050
Midlands	(-0.06)	(-0.06)	(-0.09)	(-0.05)	(-0.18)	(-0.15)	(-0.12)	(-0.1)	(-0.07)	(-0.05)
East of	-0.321***	-0.212***	-0.148	-0.022	0.231	0.094	0.039	-0.221*	-0.079	-0.013
England	(-0.06)	(-0.06)	(-0.09)	(-0.06)	(-0.18)	(-0.16)	(-0.13)	(-0.1)	(-0.06)	(-0.05)
Greater	-0.161*	-0.328***	0.061	-0.031	0.004	0.138	0.017	-0.234*	0.095	-0.021
London	(-0.06)	(-0.07)	(-0.09)	(-0.06)	(-0.23)	(-0.19)	(-0.13)	(-0.12)	(-0.07)	(-0.05)
South	-0.430***	-0.181**	-0.069	-0.019	0.007	0.040	0.030	-0.207*	-0.073	-0.006
East	(-0.06)	(-0.06)	(-0.08)	(-0.05)	(-0.17)	(-0.15)	(-0.12)	(-0.1)	(-0.06)	(-0.05)
South	-0.342***	-0.261***	-0.080	-0.042	0.006	0.125	-0.047	-0.170	-0.134*	0.027
West	(-0.06)	(-0.06)	(-0.09)	(-0.05)	(-0.18)	(-0.16)	(-0.11)	(-0.1)	(-0.06)	(-0.05)
Wales	-0.160*	-0.123	-0.094	-0.051	0.150	0.222	0.072	-0.199	0.000	-0.035
	(-0.07)	(-0.07)	(-0.1)	(-0.06)	(-0.2)	(-0.19)	(-0.13)	(-0.11)	(-0.07)	(-0.06)
Scotland	-0.358***	-0.153*	0.108	0.020	-0.053	0.095	0.014	-0.086	0.012	-0.067
	(-0.06)	(-0.06)	(-0.08)	(-0.05)	(-0.18)	(-0.15)	(-0.13)	(-0.1)	(-0.07)	(-0.05)
Northern	-0.051	0.081	0.264**	0.013	0.184	0.524***	0.035	-0.191	-0.014	-0.042
Ireland	(-0.07)	(-0.07)	(-0.09)	(-0.06)	(-0.18)	(-0.16)	(-0.14)	(-0.12)	(-0.07)	(-0.06)

	Beer on estimate (std. error)	Beer off estimate (std. error)	Spirits on estimate (std. error)	Spirits off estimate (std. error)	RTDs on estimate (std. error)	RTDs off estimate (std. error)	Cider on estimate (std. error)	Cider off estimate (std. error)	Wine on estimate (std. error)	Wine off estimate (std. error)
Low-skilled	0.194***	0.103**	0.143**	0.020	0.419***	0.157	0.040	0.005	0.017	-0.166***
household	(-0.04)	(-0.04)	(-0.05)	(-0.04)	(-0.11)	(-0.1)	(-0.08)	(-0.07)	(-0.04)	(-0.03)
Medium-skilled	0.106***	-0.004	0.125**	-0.030	0.253*	0.018	0.160*	-0.061	-0.015	-0.076**
household	(-0.03)	(-0.03)	(-0.04)	(-0.03)	(-0.1)	(-0.09)	(-0.06)	(-0.06)	(-0.03)	(-0.02)
Not	0.129***	0.109**	0.015	0.123***	0.329**	0.018	0.084	-0.008	-0.005	-0.078**
classified	(-0.03)	(-0.04)	(-0.05)	(-0.03)	(-0.12)	(-0.1)	(-0.07)	(-0.06)	(-0.03)	(-0.03)
Student	-0.078	-0.132	0.465***	-0.107	0.248	-0.066	0.017	-0.266	0.048	-0.359***
	(-0.09)	(-0.09)	(-0.09)	(-0.08)	(-0.17)	(-0.22)	(-0.13)	(-0.14)	(-0.09)	(-0.07)
Long-term	-0.129	0.162	0.090	-0.043	0.774**	0.308	0.347	0.403*	-0.047	-0.083
unemployed	(-0.11)	(-0.1)	(-0.16)	(-0.09)	(-0.25)	(-0.18)	(-0.28)	(-0.16)	(-0.17)	(-0.11)
Mixed	-0.227	-0.065	0.217	-0.199	0.013	-0.074	-0.092	-0.052	0.023	-0.248*
race	(-0.14)	(-0.15)	(-0.17)	(-0.12)	(-0.39)	(-0.32)	(-0.29)	(-0.24)	(-0.16)	(-0.11)
Asian or	-0.185	0.373***	0.088	0.057	0.373	0.091	-0.178	0.127	0.000	-0.146
Asian British	(-0.1)	(-0.09)	(-0.13)	(-0.07)	(-0.27)	(-0.21)	(-0.23)	(-0.21)	(-0.11)	(-0.08)
Black or	-0.131	-0.077	0.086	-0.148	-0.271	0.266	-0.383	-0.037	0.077	-0.201*
Black British	(-0.15)	(-0.1)	(-0.17)	(-0.1)	(-0.35)	(-0.36)	(-0.26)	(-0.18)	(-0.13)	(-0.09)
Other	-0.337**	0.189	0.019	-0.081	-0.130	-0.156	-0.335	0.399	0.031	-0.231*
	(-0.13)	(-0.13)	(-0.2)	(-0.11)	(-0.36)	(-0.32)	(-0.3)	(-0.25)	(-0.15)	(-0.11)
Constant	7.340***	7.575***	4.938***	5.391***	6.567***	5.999***	6.673***	7.317***	4.895***	6.007***
	(-0.2)	(-0.21)	(-0.26)	(-0.18)	(-0.65)	(-0.57)	(-0.43)	(-0.34)	(-0.21)	(-0.16)

*** p<0.05, ** p<0.01, *** p<0.001**

As mentioned in footnote 7 (section 4.2.2), the isoelastic Heckman correction model allows us to get a direct estimate of the income elasticity of demand for each type of alcohol – the coefficient on the measure of income we are using. As alcohol is a normal good, we would expect this to be positive, and that is exactly what we find in table A3A above. It is worth noting that wine in the off-trade has the highest estimated income elasticity and the least elastic price response of all types of alcohol estimated. This indicates that a larger proportion of the variation in quantity is explained by differences in income – and therefore affordability – rather than in price itself, which is consistent with a price elasticity estimate closer to zero.

Annex 4: Regression outputs for the participation equation

Table A4A provides the details of the regression outputs for the participation equation, with the point estimates and standard errors for each coefficient. The participation equation contains the exclusion restrictions – no consumption of pork and dummies for consumption of other types of alcohol. The final lines of the table contain both the inverse Mills ratio and the likelihood ratio test for the joint significance of the exclusion restriction for each type of alcohol.

Table A4A: Point estimates and standard errors from the participation equation

	Beer on estimate (std. error)	Beer off estimate (std. error)	Spirits on estimate (std. error)	Spirits off estimate (std. error)	RTDs on estimate (std. error)	RTDs off estimate (std. error)	Cider on estimate (std. error)	Cider off estimate (std. error)	Wine on estimate (std. error)	Wine off estimate (std. error)
Consumption	---	0.424***	0.709***	-0.133**	0.362***	-0.095*	0.594***	-0.033	0.701***	0.052**
of beer (on)	---	(-0.02)	(-0.03)	(-0.04)	(-0.04)	(-0.04)	(-0.03)	(-0.02)	(-0.02)	(-0.02)
Consumption	0.447***	---	-0.029	0.178***	-0.068	0.327***	-0.137***	0.409***	-0.115***	0.449***
of beer (off)	(-0.02)	---	(-0.03)	(-0.04)	(-0.04)	(-0.04)	(-0.03)	(-0.02)	(-0.02)	(-0.02)
Consumption	0.861***	-0.061*	---	0.148*	0.592***	0.1	0.433***	-0.067	0.515***	-0.118***
of spirits (on)	(-0.03)	(-0.03)	---	(-0.06)	(-0.05)	(-0.06)	(-0.04)	(-0.04)	(-0.03)	(-0.03)
Consumption	-0.182***	0.279***	0.198**	---	0.035	0.366***	0.046	0.240***	0.141*	0.286***
of spirits (off)	(-0.05)	(-0.05)	(-0.07)	---	(-0.11)	(-0.09)	(-0.08)	(-0.06)	(-0.06)	(-0.05)
Consumption	0.375***	-0.064	0.737***	-0.052	---	0.696***	0.375***	-0.08	-0.01	-0.112
of RTDs (on)	(-0.06)	(-0.05)	(-0.07)	(-0.12)	---	(-0.07)	(-0.06)	(-0.07)	(-0.06)	(-0.06)
Consumption	-0.151**	0.419***	0.124	0.333***	0.709***	---	0.06	0.402***	-0.134*	-0.015
of RTDs (off)	(-0.05)	(-0.05)	(-0.08)	(-0.1)	(-0.08)	---	(-0.07)	(-0.06)	(-0.06)	(-0.06)
Consumption	0.688***	-0.163***	0.432***	0.044	0.310***	0.054	---	0.761***	0.142***	-0.016
of cider (on)	(-0.03)	(-0.03)	(-0.04)	(-0.07)	(-0.05)	(-0.06)	---	(-0.03)	(-0.03)	(-0.03)
Consumption	-0.046	0.428***	-0.067	0.217***	-0.078	0.342***	0.735***	---	-0.084*	0.253***
of cider (off)	(-0.03)	(-0.03)	(-0.04)	(-0.06)	(-0.06)	(-0.05)	(-0.03)	---	(-0.03)	(-0.03)
Consumption	0.709***	-0.131***	0.511***	0.114*	0.01	-0.108*	0.138***	-0.088**	---	0.573***
of wine (on)	(-0.02)	(-0.02)	(-0.03)	(-0.05)	(-0.05)	(-0.05)	(-0.03)	(-0.03)	---	(-0.02)
Consumption	0.046*	0.404***	-0.058*	0.201***	-0.088*	0.023	0.008	0.220***	0.537***	---
of wine (off)	(-0.02)	(-0.02)	(-0.03)	(-0.04)	(-0.04)	(-0.04)	(-0.03)	(-0.02)	(-0.02)	---
No pork	-0.024	-0.171***	0.073*	-0.068	0.037	-0.142**	-0.013	-0.176***	0.036	-0.142***
consumption	(-0.02)	(-0.02)	(-0.03)	(-0.04)	(-0.05)	(-0.04)	(-0.03)	(-0.03)	(-0.02)	(-0.02)
Log price	-0.970***	0.064	0.228***	-0.039	-0.097	0.108	-0.016	0.096	0.357***	0.054
of beer (on)	(-0.05)	(-0.05)	(-0.06)	(-0.11)	(-0.09)	(-0.1)	(-0.06)	(-0.06)	(-0.05)	(-0.05)
Log price	0.041	-0.870***	0.05	-0.092	-0.06	-0.079	-0.059	-0.138**	0.097*	0.249***
of beer (off)	(-0.04)	(-0.04)	(-0.06)	(-0.07)	(-0.08)	(-0.06)	(-0.05)	(-0.04)	(-0.04)	(-0.04)
Log price	0.021	-0.006	-1.549***	-0.009	-0.155***	0.014	-0.058	-0.037	0.196***	0.001
of spirits (on)	(-0.02)	(-0.02)	(-0.03)	(-0.05)	(-0.04)	(-0.04)	(-0.03)	(-0.03)	(-0.02)	(-0.02)
Log price	0.052	0.013	-0.130*	-2.365***	-0.159	-0.116	0.015	-0.09	0.104*	-0.002
of spirits (off)	(-0.04)	(-0.04)	(-0.06)	(-0.07)	(-0.09)	(-0.07)	(-0.06)	(-0.05)	(-0.05)	(-0.04)
Log price	0.078*	-0.017	-0.005	0.079	-0.204**	0.07	-0.093	0.029	0.044	0.07
of RTDs (on)	(-0.04)	(-0.04)	(-0.06)	(-0.09)	(-0.08)	(-0.08)	(-0.06)	(-0.05)	(-0.04)	(-0.04)
Log price	-0.005	-0.005	0.104*	-0.114	0.036	-0.138*	-0.007	0.071	0.052	0.04
of RTDs (off)	(-0.03)	(-0.03)	(-0.04)	(-0.06)	(-0.06)	(-0.05)	(-0.04)	(-0.04)	(-0.03)	(-0.03)
Log price	0.042	-0.105*	0.316***	-0.093	-0.167	-0.115	-0.414***	-0.047	0.065	0.045
of cider (on)	(-0.05)	(-0.05)	(-0.07)	(-0.1)	(-0.1)	(-0.1)	(-0.06)	(-0.06)	(-0.06)	(-0.05)
Log price	0.02	-0.037	0.156**	0.061	0.032	0.077	0.003	-0.575***	0.047	0.077*
of cider (off)	(-0.03)	(-0.03)	(-0.06)	(-0.07)	(-0.08)	(-0.06)	(-0.05)	(-0.04)	(-0.04)	(-0.04)
Log price	-0.031	0.002	0.205***	0.151**	-0.048	-0.013	-0.105***	0.033	-0.679***	0.013
of wine (on)	(-0.02)	(-0.02)	(-0.03)	(-0.05)	(-0.05)	(-0.05)	(-0.03)	(-0.03)	(-0.02)	(-0.02)
Log price	-0.060*	0.024	0.013	-0.047	-0.123*	-0.068	-0.012	-0.074*	0.101**	-1.567***
of wine (off)	(-0.03)	(-0.03)	(-0.05)	(-0.05)	(-0.05)	(-0.05)	(-0.04)	(-0.03)	(-0.03)	(-0.04)
Consumption of	0.058	0.022	0.296***	-0.134	0.075	-0.063	0.06	0.16	8.71	-0.230**
sparkling wine (on)	(-0.07)	(-0.07)	(-0.08)	(-0.15)	(-0.12)	(-0.15)	(-0.08)	(-0.09)	(-99453.49)	(-0.07)
Consumption of	-0.095*	-0.037	-0.045	0.246**	0.073	0.107	-0.023	0.046	0.03	10.505
sparkling wine (off)	(-0.04)	(-0.04)	(-0.04)	(-0.08)	(-0.09)	(-0.08)	(-0.06)	(-0.05)	(-0.05)	(-118318.39)
Consumption of	0.185	0.006	0.318**	0.209	-0.045	0.057	0.026	-0.037	9.025	-0.504***
fortified wine (on)	(-0.11)	(-0.1)	(-0.12)	(-0.18)	(-0.19)	(-0.21)	(-0.13)	(-0.14)	(-79137.31)	(-0.11)
Consumption of	-0.057	-0.015	-0.048	0.285***	-0.227	0.118	-0.139*	0.218***	-0.094*	9.567
fortified wine (off)	(-0.04)	(-0.04)	(-0.07)	(-0.08)	(-0.13)	(-0.08)	(-0.07)	(-0.05)	(-0.05)	(-138815)
Consumption of	0.304***	-0.05	11.278	0.012	0.203**	-0.131	0.016	-0.021	-0.168**	0.041
spirits no mixer (on)	(-0.06)	(-0.05)	(-23993.44)	(-0.11)	(-0.07)	(-0.1)	(-0.06)	(-0.07)	(-0.05)	(-0.05)
Consumption of	0.127*	0.056	-0.077	12.381	-0.105	-0.04	-0.071	-0.029	-0.065	0.05
spirits no mixer (off)	(-0.06)	(-0.05)	(-0.08)	(-3630.86)	(-0.12)	(-0.09)	(-0.08)	(-0.06)	(-0.06)	(-0.06)
Smoking	0.009	0.179***	0.104***	0.028	0.226***	0.151***	0.070*	0.088***	-0.237***	-0.135***
household	(-0.02)	(-0.02)	(-0.03)	(-0.04)	(-0.04)	(-0.04)	(-0.03)	(-0.02)	(-0.02)	(-0.02)
Number of people	0.157***	0.121***	0.047**	0.014	0.210***	0.100***	0.089***	0.082***	0.024	0.022*
of drinking age	(-0.01)	(-0.01)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.02)	(-0.01)	(-0.01)	(-0.01)
Household with all	-0.250***	-0.256***	-0.144*	-0.167*	-0.603**	-0.273**	-0.313***	-0.343***	-0.072	-0.070*
members over 75	(-0.03)	(-0.04)	(-0.07)	(-0.08)	(-0.22)	(-0.09)	(-0.08)	(-0.05)	(-0.04)	(-0.03)

	Beer on estimate (std. error)	Beer off estimate (std. error)	Spirits on estimate (std. error)	Spirits off estimate (std. error)	RTDs on estimate (std. error)	RTDs off estimate (std. error)	Cider on estimate (std. error)	Cider off estimate (std. error)	Wine on estimate (std. error)	Wine off estimate (std. error)
Log real equivalised	0.334***	0.090***	0.299***	0.226***	0.056	0.051	0.165***	0.023	0.608***	0.387***
expenditure	(-0.02)	(-0.02)	(-0.03)	(-0.04)	(-0.04)	(-0.04)	(-0.03)	(-0.02)	(-0.02)	(-0.02)
Time	-0.003*	0.002	-0.005*	0.016***	-0.017***	0.004	0.007**	0.012***	-0.014***	0.006***
trend	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
North West and	-0.035	0.071	0.473***	-0.004	0.076	-0.045	-0.153*	-0.004	0.199***	0.096*
Merseyside	(-0.04)	(-0.05)	(-0.07)	(-0.1)	(-0.11)	(-0.1)	(-0.07)	(-0.06)	(-0.06)	(-0.05)
Yorkshire and	0.072	0.061	0.256***	0.021	0.045	-0.066	-0.018	0.064	0.049	0.090
the Humber	(-0.05)	(-0.05)	(-0.07)	(-0.1)	(-0.11)	(-0.1)	(-0.07)	(-0.06)	(-0.06)	(-0.05)
East	0.045	0.051	0.208**	-0.019	0.133	0.005	0.001	0.072	0.082	0.029
Midlands	(-0.05)	(-0.05)	(-0.07)	(-0.11)	(-0.11)	(-0.1)	(-0.07)	(-0.06)	(-0.06)	(-0.05)
West	0.003	0.052	0.371***	-0.012	0.042	0.016	0.141*	0.046	0.147*	0.038
Midlands	(-0.05)	(-0.05)	(-0.07)	(-0.11)	(-0.11)	(-0.1)	(-0.07)	(-0.06)	(-0.06)	(-0.05)
East of	-0.074	0.054	0.208**	0.081	0.151	0.011	-0.087	0.025	0.213***	0.097*
England	(-0.05)	(-0.05)	(-0.07)	(-0.1)	(-0.11)	(-0.1)	(-0.07)	(-0.06)	(-0.06)	(-0.05)
Greater	-0.092	0.101	0.517***	0.071	-0.151	-0.118	0.038	-0.105	0.313***	0.177**
London	(-0.05)	(-0.05)	(-0.08)	(-0.12)	(-0.13)	(-0.11)	(-0.08)	(-0.07)	(-0.06)	(-0.05)
South	-0.063	0.020	0.341***	0.083	0.054	-0.060	-0.063	0.005	0.256***	0.200***
East	(-0.05)	(-0.05)	(-0.07)	(-0.1)	(-0.11)	(-0.1)	(-0.07)	(-0.06)	(-0.06)	(-0.05)
South	-0.069	0.012	0.279***	0.032	0.006	-0.066	0.222**	0.086	0.198***	0.121*
West	(-0.05)	(-0.05)	(-0.07)	(-0.1)	(-0.11)	(-0.1)	(-0.07)	(-0.06)	(-0.06)	(-0.05)
Wales	-0.137**	-0.003	0.114	-0.212	0.088	-0.134	0.071	0.107	0.191**	0.110*
	(-0.05)	(-0.05)	(-0.08)	(-0.12)	(-0.12)	(-0.12)	(-0.08)	(-0.07)	(-0.07)	(-0.05)
Scotland	-0.281***	0.022	0.370***	0.042	0.021	0.124	-0.143	-0.034	0.194**	0.145**
	(-0.05)	(-0.05)	(-0.07)	(-0.11)	(-0.11)	(-0.1)	(-0.08)	(-0.06)	(-0.06)	(-0.05)
Northern	-0.390***	-0.117*	0.708***	0.100	0.353**	0.221*	-0.045	-0.125	0.083	0.037
Ireland	(-0.05)	(-0.05)	(-0.08)	(-0.12)	(-0.11)	(-0.1)	(-0.08)	(-0.07)	(-0.06)	(-0.05)
Low-skilled	-0.133***	-0.117***	0.031	0.043	0.176*	0.164*	-0.020	0.055	-0.185***	-0.312***
household	(-0.03)	(-0.03)	(-0.05)	(-0.07)	(-0.07)	(-0.06)	(-0.05)	(-0.04)	(-0.04)	(-0.03)
Medium-skilled	-0.101***	-0.055*	0.089*	-0.041	0.054	0.034	0.026	0.047	-0.022	-0.085**
household	(-0.03)	(-0.03)	(-0.04)	(-0.06)	(-0.06)	(-0.06)	(-0.04)	(-0.04)	(-0.03)	(-0.03)
Not	-0.168***	-0.268***	-0.058	0.029	-0.118	0.008	-0.184***	-0.075	-0.138***	-0.333***
classified	(-0.03)	(-0.03)	(-0.04)	(-0.06)	(-0.07)	(-0.06)	(-0.04)	(-0.04)	(-0.03)	(-0.03)
Student	-0.350***	-0.118	0.646***	-0.429*	0.271*	-0.015	0.257**	0.025	-0.210*	-0.166*
	(-0.07)	(-0.07)	(-0.09)	(-0.22)	(-0.12)	(-0.14)	(-0.09)	(-0.09)	(-0.08)	(-0.07)
Long-term	-0.289***	-0.208**	-0.160	-0.050	0.183	0.330**	-0.204	-0.050	-0.316**	-0.645***
unemployed	(-0.07)	(-0.07)	(-0.14)	(-0.17)	(-0.15)	(-0.12)	(-0.13)	(-0.1)	(-0.12)	(-0.08)
Mixed	-0.238*	-0.247*	0.074	-0.018	-0.006	0.120	-0.064	-0.056	-0.418**	-0.026
race	(-0.1)	(-0.11)	(-0.15)	(-0.23)	(-0.24)	(-0.19)	(-0.17)	(-0.14)	(-0.14)	(-0.1)
Asian or	-0.657***	-0.372***	-0.399***	-0.366*	-0.263	-0.078	-0.366***	-0.571***	-0.544***	-0.681***
Asian British	(-0.06)	(-0.06)	(-0.1)	(-0.16)	(-0.15)	(-0.12)	(-0.11)	(-0.1)	(-0.08)	(-0.06)
Black or	-0.778***	-0.140*	-0.285*	-0.008	-0.001	-0.242	-0.096	-0.053	-0.213*	-0.338***
Black British	(-0.09)	(-0.07)	(-0.13)	(-0.16)	(-0.19)	(-0.19)	(-0.13)	(-0.1)	(-0.09)	(-0.07)
Other	-0.356***	-0.358***	-0.439**	-0.224	-0.160	-0.066	-0.252	-0.284*	-0.484***	-0.365***
	(-0.08)	(-0.09)	(-0.15)	(-0.22)	(-0.23)	(-0.18)	(-0.16)	(-0.13)	(-0.12)	(-0.08)
Constant	-3.287***	-3.125***	-1.436***	-3.272***	-3.165***	-2.976***	-3.410***	-3.129***	-3.838***	-2.968***
	(-0.15)	(-0.15)	(-0.23)	(-0.32)	(-0.34)	(-0.3)	(-0.22)	(-0.19)	(-0.18)	(-0.15)
atan(ρ)	-0.261***	-0.654***	0.244***	0.241***	-0.150	-0.186	-0.259***	-0.550***	-0.382***	-0.346***
	(-0.03)	(-0.04)	(-0.04)	(-0.05)	(-0.13)	(-0.15)	(-0.06)	(-0.06)	(-0.04)	(-0.03)
log(σ)	0.066***	-0.016	-0.096***	-0.437***	-0.269***	-0.354***	-0.047*	-0.034	-0.198***	-0.096***
	(-0.01)	(-0.02)	(-0.01)	(-0.01)	(-0.03)	(-0.04)	(-0.02)	(-0.02)	(-0.01)	(-0.01)
Inverse Mills ratio	-0.272	-0.565	0.217	0.153	-0.114	-0.129	-0.242	-0.484	-0.299	-0.302
LR test of independence	chi-sq (1)	chi-sq (1)	chi-sq (1)	chi-sq (1)	chi-sq (1)	chi-sq (1)	chi-sq (1)	chi-sq (1)	chi-sq (1)	chi-sq (1)
H0: ρ=0	75.97***	145.67***	43.35***	25.36***	1.30	1.42	16.82***	64.73***	57.28***	135.78***

*** p<0.05, ** p<0.01, *** p<0.001**

The inverse Mills ratio (λ) is estimated by multiplying ρ (the correlation coefficient between unobservables and the propensity to drink) by σ (the standard deviation of the residual). Because $\sigma > 0$ by definition, the inverse Mills ratio will be statistically different from zero if ρ is statistically different from zero, which is the test that is conducted in the final line of the table of results. If ρ – and by association λ – is statistically different from zero, then we can reject the hypothesis that there is no correlation between the inverse Mills ratio and participation in the sample, giving us confidence in the relevance of using the Heckman correction model.